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СТРОИТЕЛЬНЫЕ МАТЕРИАЛЫ И ИЗДЕЛИЯ

Пособие для студентов и магистрантов
строительных специальностей

BUILDING MATERIALS AND ITEMS

Manual for students and masters
of building specialities

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строительных материалов и изделий различного назначения.

Предназначен для студентов и магистрантов строительных специальностей вузов.

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PREFACE

This manual deals with properties of building materials and techniques for manufacturing building materials and items on an industrial scale. The building materials industry plays an important part in the economy and progress of the each country. The building materials industry is in continual development, the range of products is being expanded, and novel techniques for optimizing production processes are being introduced on an industrial scale.

The multiformity of service conditions to which buildings and installations are exposed and of production process parameters underlie the great variety of requirements upon the building materials, hence, the wide range of their properties, to cite but a few: strength at ordinary and high temperatures (the latter characterizing the heat- or the fire-resistance of a material); water-resisting property; resistance to attack by various salts, acids and alkalis; resistance to erosion by slag (of a particular importance in metallurgical processes) and others. As essential in construction and engineering is the permeability (or the impermeability) of materials with respect to liquids, gases, heat, cold, electric current, radioactive radiation. The materials for finishing dwelling and public building premises, gardens and parks are required no please the eye, be durable and strong.

A material with universal properties is as yet a challenge of the future.

Building materials are widely used in construction as slabs for walls and foundations of buildings, as facing wares, for exterior and interior walls, and floors of buildings, for roads, sidewalks, and also as heat- and water-insulating materials. All building materials are generally classified according their purpose (constructional, foundry facing, acoustic, heat-insulating and others), and kinds of materials (natural stone, ceramic, glass, polymers and others). As it is known, the building materials can be organic (wood, polymers, bitumen) and mineral (stone, ceramic, glass, metal). Organic materials are obtained from wood, oil, gas; mineral ones are obtained from mineral rocks (sand-glass, clay-ceramic, ore-metal). The shape of building materials may be friable (sand, crushed stone), leafy (glass, metal), little and big blocks (from natural stones, ceramic and concretes) and liquid (glue, colours).

Each building material is covered by a State Standard (GOST), Technical Specification (TU) or EN ISO, which gives the definition (name) of the material and specifies its principal properties and the requirements upon it, testing methods (to establish and quantify the properties) and rules for its acceptance, transportation and storage. In practical construction work, the State Standards, the Technical Specifications and EN ISO are complemented by Construction Norms and Rules. Said documents are revised at regular intervals of time to keep up with the continual advances in techniques for manufacturing building materials and in construction practices which impose ever stringent requirements upon the building materials and necessitate expansion of their range.

Chapter 1. CHIEF PROPERTIES OF BUILDING MATERIALS

As it is known the fields of application of building materials dictate their properties.

The properties of building materials determine their chemical and mineralogical composition and their structure. According to the microstructure, materials are classified into: crystalline (stone, metal), amorphous (glass, bitumen), coagulation-viscous (colours composition, melts of metal and glass, plastic concrete mix), according to macrostructure – dense (metal), porous (brick), cellular, layered (shale), fibred (wood), friable (sand).

The properties of building materials are classified as physical, chemical, mechanical and technological.

Physical properties of materials include their characteristic density, structure, their relation to water, frost, heat, fire, sound and radioactive rays.

Chemical properties of materials define their ability to participate in chemical reactions with decrease or increase their strength.

Mechanical properties determine the resistance of materials to different forces. Technological properties are necessary to receive manufactured articles and constructions, for example, plasticity, viscosity, weldability (metal).

Physical properties of materials include true and average density (kg/m^3), porosity (%), and hydro-physical, heat-physical, acoustic properties.

The true density is the mass (kg) of one cubic metre (m^3) substance which the material consists of. The true density is determined with the formula

$$\rho = \frac{m}{V},$$

where m – mass of a substance in the absolute dense state, kg;

V – volume of a material, m^3 .

The average density (kg/m^3) is the mass of a unit volume of the material in natural state, (with voids and pores included)

$$\rho_{av} = \frac{m}{V},$$

where m – mass of a material in the natural state, kg;

V – volume of a material, m^3

The average density of a material may vary as a function of porosity and void content.

Loose materials (sand, crushed stone, cement and others) are characterized by their apparent density (p_f). The volume of these materials is considered to include not only the pores and voids inside the grains of the material, but also the voids between them.

$$p_f = \frac{m}{V},$$

where m – mass of a loose material definite, kg;

V – volume of a material in loose state, m^3

The porosity (%) of a material is the relative volume of the pores it contains.

$$\rho = (1 - \frac{\rho_{av}}{\rho}) \cdot 100,$$

where ρ_{av} – average density of a material, kg/m^3 ;

ρ – true density of a material, kg/m^3 .

Pores are small cells in a material filled with air or water. Pores may be open or closed, little and large. Little closed pores are filled with air.

The material which has many closed pores possesses good heat insulation properties. The porosity of a material may influence its other properties such as average density, strength, thermal conductivity, frost resistance, water permeability. Walls of buildings are made of porous materials.

Void content – voids filled with air are spaces between grains of a loose material (sand, crushed stone, etc). The void content ($P_{v.c.}$) of sand and crushed stone ranges from 35 to 45%.

$$P_{v.c.} = (1 - \frac{\rho_f}{\rho_{av}}) \cdot 100,$$

where ρ_f – apparent density of a loose material, kg/m^3 ;

ρ_{av} – average density grain of a material, kg/m^3 .

The properties of materials with respect to the action of water are characterized by their **hydro-physical properties**. These properties of building materials are generally classified as hygroscopicity, water absorption, water release, water permeability, frost resistance, weathering or air resistance.

Hygroscopicity is the property of a material to absorb water vapour from air. It is governed by the nature of the substance involved, by air temperature and relative humidity, by the type of pores, their number and size. Surfaces of some materials (called hydrophilic) attract water well, while surfaces of others (known as hydrophobic) repulse water.

Under other conditions being equal, the hygroscopicity of material depends on its surface area including that of open pores and capillary channels. Materials of equal porosity, but with smaller open pores and capillary channels prove to be more hygroscopic than materials with larger pores. Hygroscopic is characterized by quantity of absorb water vapour from air (%).

Water absorption is the ability of material to absorb and retain water. It is described by the amount of water absorbed by an initially dry material plunge in water, and is expressed in per cent of the mass (water absorption by mass) or of the volume (water absorption by volume) of the dry material.

The value of water absorption by mass (%) is determined by means of the formula

$$\omega_m = \frac{m_2 - m_1}{m_1} \cdot 100,$$

and that by volume (%) with the aid of the formula (as volume water equals mass water by density one kg/m³).

$$\omega_0 = \frac{m_2 - m_1}{V} \cdot 100,$$

where m_2 – mass of a material in water saturated state, kg;

m_1 – mass of the material in dry state, kg;

V – volume of the material in natural state, m³.

Water absorption is always less than the true porosity since some of the pores are closed i.e., isolated from the surrounding medium and not accessible to water. Water absorption by volume is always less than 100%, whereas water absorption by mass of very porous materials may exceed 100%.

Water absorption of building materials is governed chiefly by the volume of the pores, their shape and sill. It is also influenced by the nature of materials and their water-retaining properties. Saturation with water greatly affects the properties of materials: the bulk, density and heat conductivity of some go up, whereas others, e.g., wood, clay, tend to swell, so that their volume increases and their strength decreases because the links between the particles are broken by the penetrating molecules of water.

The ratio of the compressive strength of material saturated with water (R_w) in dry state (R_d) is called the coefficient of softening

$$R_\omega = \frac{R_w}{R_d}$$

and describes the water resistance of materials. For soaking materials it equals 0 (clay), whereas others (metal, glass) fully retain their strength under the action

of water and their coefficient of softening is 1. Materials with coefficient of softening 0.8 and higher are referred to as water – resisting materials. Materials with a coefficient of softening less than 0.8 should not be permanently exposed to the action of moisture.

Water release

The property of water release is reverse to water absorption. With fall of the humidity and rise of the temperature, the materials will release moisture to the surrounding medium. The rate of drying depends first on temperature and also on the difference between the moisture of the material and the relative humidity of the air – the greater the difference, the more intensive is the drying of the material secondly; the rate of drying is affected by the properties of the material itself and the nature of its porosity. Water – repellents and materials with large pores release their moisture quicker than fine – porous and hydrophilic materials. The water release for building materials is described by the intensity of water loss (%) at a relative air humidity of 60% and temperature of 20%.

Air resistance (weathering resistance).

This property of material is its ability to endure repeated moistening and drying over prolonged periods of time without either suffering considerable deformation or losing mechanical strength.

Variations in humidity take place in many materials by changes in volume: the materials swell when moisture content increases and shrink, when it decreases. Repeated moistening and drying cause alternating stresses in the material of building constructions and may result, in the course of time, in the loss of load-bearing capacity (failure).

Water permeability determines the capacity of material to let through water under pressure. This property is estimate by the coefficient of filtration, which is equal to the amount of water penetrating in one hour at a constant pressure through 1m^2 of the material being tested. Water permeability depends on contain of open pores. Dense materials (steel, glass, bitumen, most plastics) are impervious to water (waterproof).

Frost resistance is the ability of a water-saturated material to endure repeated freezing and thawing with out visible signs of failure or considerable decrease of mechanical strength. The disintegrate being the result of water increase contained inside their pores increases in volume by up to 9% in the process of freezing.

Frost resistance of materials is determined by freezing water-saturated specimens at the temperature between $-15 - 17^\circ\text{C}$ and subsequently thawing them out.

The frost resistance of material depends on its density and the degree of its saturation with water. Dense materials are frost resistant. Of the porous materials, frost resistant are only those in which most of the pores are closed. Mate-

rial is considered frost resistant when its strength decreases by not more than 15 to 25% and the loss in weight as result of spalling does not exceed 5% after a prescribed number of freezing and thawing cycles. When specimens show no signs of failure after freezing, their frost resistance is defined by the frost resistance coefficient which is calculated according to the formula:

$$K_{fr} = \frac{R_{fr}}{R_{ws}},$$

where R_{fr} – compressive strength of material after the frost resistance test, Pa;

R_{ws} – compressive strength of water – saturated material before the test, Pa .

A frost resistant material is one whose coefficient K_{fr} is not less than 0.75.

By the number of freezing and thawing cycles which materials are capable to withstand, they are subdivided into grades frost resistance stamp F 10, 15, ... 200 and over (F is an abbreviation for frost).

Under laboratory conditions, specimens are frozen in refrigerating chambers. One or two freezing cycles in the chamber are equivalent to 3 or 5 years of atmospheric exposure. There is also a faster testing method in which specimens are soaked in a 5% solution of chloride sodium and then frozen at a temperature to -18 or -50°C with crystals water. Crystals of salt together formed inside the pores of the stone, press against the walls of the pores even stronger than the freezing water itself. The reason for freezing the specimens at such a low temperature is explained by congeals in small capillary channels only at temperatures between -10 and -50°C . One cycle of faster testing is equivalent to 10 or even 20 cycles of direct freezing tests.

Heat-physical properties of materials include heat conductivity, heat capacity, thermal resistance, hot resistance, fire resistance, refractoriness.

Heat conductivity of a material is its ability to conduct heat. All materials conduct heat to a different degree. The heat conductivity of material is quantitatively evaluated by a coefficient which is equal to the quantity of heat flowing in 1 hour through a specimen of 1 m^2 area 1 m thick when the temperature difference between its opposite and parallel flat surfaces is 1°K .

The heat conductivity of material is governed by a number of factors: nature of the material, its structure, porosity, character of pores, humidity and temperature at which the heat exchange takes place. Materials with closed pores have lower heat conductivity than those with communicating pores. Fine-porous materials have lower heat conductivity than those with large pores. As it is known the air inside the large and communicating pores is freer to move, which enhances heat transfer. Heat conductivity of homogeneous material depends on its average density. When it decreases, heat conductivity drops, and vice versa.

Heat conductivity is greatly affected by humidity. The humid materials have higher heat conductivity than dry ones, because heat conductivity of water is 25 times higher than that of air.

The coefficient of heat conductivity is the basis index for various heat-insulating and structural and heat insulating materials and manufactured articles.

The values of heat conductivity for various categories of materials have been set as follows ($\text{W}/\text{m}^\circ\text{C}$).

Heat conductivity is of major importance for materials used to build walls of heated buildings and to insulate various thermal equipments.

The heat capacity of a material is its ability to absorb or give off heat on heating or cooling, this ability being described in quantitative terms by a coefficient which (kJ) is equal to the quantity of heat required to heat 1 kg of material by 1°C . The heat capacity of steel is 0,46; of heavy concrete is 0,90; of wood is 2,4; water – 4,0 $\text{kJ}/\text{kg} \cdot ^\circ\text{K}$.

Thermal resistance of a material is characterized by its ability to endure a certain number of cycles of sharp temperature variations without destruction. Thermal resistance depends on the degree of homogeneity of the material and the coefficients of linear expansion of its constituents. The lower the latter values, the higher is the thermal resistance of the material. Glass and granite may be examples of materials with poor thermal resistance.

Hot – resistance is the ability of a material being resistant at temperature of exploitation from 1000°C and below.

The hot resistant materials work under his condition without increase of deformation and decreases of its strength.

Refractoriness is the ability of a material to withstand prolonged action of high temperature without melting or losing shape. In this category there are three varieties of material – refractory, high-melting and low-melting. Materials capable of resisting a prolonged action of temperatures from 1580°C and higher are known as refractory. High-melting materials withstand temperatures from 1350 to 1580°C and low-melting materials – temperature below 1350°C .

Fire-resistance is the ability of materials to resist the action of fire without substantial deformation or loss of strength. According to their fire-resistance building materials may be subdivided into noncombustible, fire-resistive and combustible. Noncombustible materials neither smoulder nor char under the action of fire. Natural (rock) and non-organic mineral materials (ceramic) belong to this category. However, some of these materials (glass, metal) suffer considerable deformation and melt. That is why they cannot be referred to noncombustible materials. Fire-resistive materials are ones which char, smoulder and ignite with difficulty when exposed to the action of flame but continue to burn or smoulder only in the presence of flame. Combustible materials burn and smoulder

under the action of fire and go on burning after the starting flame is removed. All organic materials, not treated with fire-proof compounds, fall into this category.

Acoustic properties of a material are characterized by their relation to sound waves and noises. Sound waves of lower or higher frequencies cannot be seen by human beings. Sounds may be divided into musical sounds, noises and sound pulses. The quantity of energy carried by a sound wave per 1 s through an area of 1 cm² is known as sound intensity. Sound intensity is measured in decibels, and its physiological characteristic (loudness) in phonon. Velocity of sound in the air at 15°C is equal to 340 m/s. Noise is a combination of various sounds rapidly changing in pitch and intensity. In buildings noises may be audible and inaudible (ultra sound) they may originate in the air or by direct impact. A prolonged, action of audible sound that of a high pitch sound is detrimental to human health. Noise can be considerably lowered by constructional acoustics which are concerned with sound insulation of exterior walls and floors against solid-borne noises and sound-absorbing for ceilings against air-borne noises. The sound-absorbing materials probably a lot of open pores and soundproof probably be springy. Sources of high-intensity vibration noises are generally various engines and mechanisms. Spreading of vibration noises can be considerably lowered if vibration insulating and vibration-absorbing materials are used.

Radiation resistance is a physical property of a material characterized by its ability to resist the action of radiation rays without substantial deformation and loss of strength. The radiation rays raise temperature of materials and alter its microstructure. Radiation steady materials due to arrest gamma rays and neutron fluxes which are dangerous to living organisms. Protection against neutron radiation is provided by materials containing a large amount of combined water, and against gamma rays, by high-density materials (lead, extra-heavy concrete).

Chemical properties are the ability of material to withstand the action of acids, alkalis, salt solutions and gases. Sanitary facilities, sewer pipes, materials for walls, floors, ceilings, chemical factors and also hydraulic engineering installations are most frequently attacked by corrosive liquids and gases and by sea water which contains a large quantity of dissolved salts.

Chemical resistance is defined by the chemical resistance coefficient which is calculated according to the formula

$$K_{ch.res} = \frac{R_2(m_2)}{R_1(m_1)},$$

where $R_1(m_1)$ – compressive strength (or mass) of material before the test, Pa (g);

$R_2(m_2)$ – compressive strength (or mass) of material after the chemical resistance test, Pa (g).

A chemical resistant material is one whose coefficient ($K_{ch.res.}$) is not less than 0, 90.

Mechanical properties of building materials are characterized by the ability of a material to resist all external actions involving the application of force. The various mechanical properties are generally divided into the following categories: compressive strength, bending strength, hardness.

The strength of building materials is described by their ultimate strength, which is the stress corresponding to the load destructing a specimen of the material. Ultimate strength (Pa) in compression and tension (R) is computed with the formula

$$R = \frac{P}{F},$$

where P – breaking load, N (kgf);

F – area of the initial cross specimen, mm² (cm²).

Compressive strength of material is found experimentally by testing specimens in mechanical or hydraulic presses. Specimens shaped as cubes with sides measuring from 2 to 30 cm are specially prepared for the purpose. The strength of material depends on its structure, average density, moisture content, chemical composition, direction of load application and the rate of load application.

The bending strength (MPa) is determined with the aid of the following formulas:

for a single concentrated load and a bar of a rectangular cross section

$$R_b = \frac{3Pl}{2bh^2};$$

for two equal loads located symmetrically with respect to the bar axis

$$R_b = \frac{3P(l-a)}{bh^2},$$

where P – breaking load, N (kgf);

l – span between supports, mm (cm);

a – distance between loads, mm (cm);

b and h – width and height of the bar's cross section, respectively, mm (cm).

The values of safety factors, which are so vital for the preservation and the service life of constructions, are specified by design standards and depend on the type and the quality of the material, service life of the building and special engineering calculations.

Hardness is the ability of material to resist penetration in its surface by a harder body. Hardness of stone materials is found with the aid of Moh's scale of

hardness, which is a list of ten minerals arranged in the order of increasing hardness. The hardness of a material lies between the hardness of two adjacent materials, one of which scratches and the other is scratched by the tested material. Hardness of metals and plastics is found on the diameter of imprint of a steel ball.

The abrasion resistance of a material is characterized by the loss of its initial mass referred to 1 sq. metre (m^2) of the surface area being abraded. Materials tested to abrasion resistance are designed for floors, roadway wearing courses, stair treads.

Impact strength is of prime importance in materials for floors and road surfaces. The ultimate strength of material subjected to impact of specimen per its unit volume, J/m^3 . Materials are tested for impact strength in an impact testing machine.

Wear is the failure of a material under the combined action of abrasion and impacts. Wear resistance is evaluated by the loss in mass expressed in per cent of road surfaces and materials designed for floors in industrial enterprises are subjected to wear.

Durability is the ability of a material to resist the combined action of atmospheric and other factors in the course of many years. These include variations in temperature and humidity, attacks by gases contained in the air or salts dissolved in water or the combined action of water, frost and insolation and also the application of the force. Durability is defined in the years of exploitation of building materials with out substantial deformation or loss of strength.

Chapter 2. ORGANIC BUILDING MATERIALS

Organic building materials include wooden materials and items, polymer-based materials and also organic binders and bitumen-based materials.

2.1. Wooden Materials and Items

In modern building practice wood is extensively used for walls and floors of buildings, carpentry and graded plank items, as well as prefabricated standard wooden cottages. A great quantity of wood is consumed in building and installation work for making piles, poles, various loads-bearing components, casings, scaffolds.

Glued wood components for e.g. beams, trusses, arches, frames and roofs of buildings and installations – are very effective in chemically aggressive media because their service life is 1,5 times greater than that of steel or reinforced concrete.

In building conifer (pine, spruce, larch, fir) and broad-leaved (oak, birch, alder, aspen, beech, lime, maple) wood species are used. Pine is used for building walls of dwelling houses, bridges, poles, window sashes, transoms, floors. Larch is used for the manufacture of poles, girders, and in general hydraulic engineering construction. Broad-leaved species mostly used in building practice for trimming work because it has pleasant texture and colour.

2.1.1. Structure and Properties of Wood

Wood is an organic natural, fibred, porous (macrostructure) material, which consists of living and dead cells of various size and shape (microstructure). A living cell provides the growth of a tree. After a while these cells die and become hard and strong. Macrostructure of wood is studied by cutting the trunk in three directions: cross-sectional, radial cut and tangential. The cross-section has layers formed during the growing season (spring-autumn). They are called annual rings. Each annual ring consists of light (early) wood which is porous and unstable and dark (late) wood, which is dense, water resistance and strong. The higher the percentage of the late wood, the stronger the wood is.

Wood as building material has a great number of valuable properties: high compressive and bending strength, small true and average density, low heat conductivity, it is also easy to mechanical working and decoration. Wood has several negative properties: its anisotropy results in different strength, heat conductivity and electrical conduction in length and across fibres; wood is a hydrophilic and combustible material.

Properties of wood are greatly affected by moisture content. Therefore its principal properties (strength, average density, heat conductivity) calculated with the use of standard moist are equal 12%. Wood may contain water in three forms: capillary (or free), hygroscopic and chemically bonded. Moisture content of wood exposed to prolonged contact with air of constant relative humidity and temperature is called the equilibrium moisture content. Because of structural nonuniformity wood shrinks under dry or swells irregularly in various directions. Linear shrinkage along the fibres lies between 0,1 and 0,3%, in radial direction between 3 and 6%, in tangential direction between 7 and 12%. To expel different shrinkage in time to exploitation wood dry before humidity from 15 to 20% (air-dry) in order to use it on air, or before humidity from 8 to 13% (room-dry) in order to use it indoors.

The following drying methods are in current use: air (natural), chamber, electric, in hot liquids, the chief methods being air and chamber drying.

The true density of wood is approximately equal for all species and averages $1,54 \text{ t/m}^3$.

Average density of wood depends on the volume of pores and moisture content. For various wood species the average density is less than true. Average density of wood characterizes its physical and mechanical properties (water absorption, heat conductivity, strength).

Heat conductivity of wood is low and depends on the porosity, moisture content, orientation of fibres, species and average density of wood. Heat conductivity of wood being a greater as the average density of wood and its moisture content becomes greater because the amount of air entrapped inside cavities decreases.

Due to anisotropy, the resistance of wood to mechanical action differs the fibre orientation. Compressive strength parallel to fibres of wood at 12% moisture content varies greatly with the wood species, the range being from 30 to 100 MPa, and compressive strength perpendicular to fibres of wood amounts from H to 25 MPa.

Wood of higher average density foes a greater strength, the latter being also affected by the percentage of late wood. Wood withstands static lending well. Bending strength is equal to 50-100 MPa (at 12% moisture content), depending on the species of wood.

Wood has a high tensile strength parallel to fibres. For the generally used species, this value ranges from 80 to 190 MPa.

However wood cannot be extensively used in structure working under crushing and shearing stresses which wood resists poorly. Presence of defects, decay regions and also greater moisture content of wood has a lower strength.

Departures from the normal structure and flaws which affect its engineering properties are classified as defects of wood. Defects appear both during the growth of trees and during storage and service. According to their causes, defects are divided into the following main groups: incorrect structure (trunk eccentricity, double heartwood, knotty wood and other), mechanical damage, damage by fungi, damage by insects. Damage caused by fungi is very widespread. Fungi develop in the presence of oxygen, moisture and favourable temperature. Some fungi may develop only on growing trees, others, on felled ones, and still others, both on growing and felled trees. Wood with a moisture content of 20% and less or wood placed in water or exposed to frost does not decay.

Decay of wood stops as soon as it dries, and all the fungi perish. Wood in construction items or in storage may be attacked by fungi and insects. Wood can be protected against decay and its service life in structures increased by preventing its humidification by structural means, such as painting or coating, leaching and impregnating with antiseptics. Antiseptics are substances which are poisonous for wood-attacking fungi. They should be harmless to man and domestic animals. Antiseptics are subdivided into water-soluble, oil and paste varieties.

Water-soluble antiseptics are used for treating wood not exposed to moisture. Because of high inflammability and sharp odour, oil antiseptics are used only for impregnating or coating wood placed in the open air, soil or water. Antiseptic pastes are subdivided according to their binders into bitumen, silicate, etc., varieties.

Wood preservation with liquid compositions includes surface preservation, impregnation in hot-cold and high-temperature baths, impregnation under pressure.

Wood is very inflammable, this being one of its major shortcomings. Wood can be protected against fire by plastering, coating with gypsum or asbestos-cement sheets or surface treatment with fire resistant substances. There are two surface treatment techniques, namely, painting and impregnation with fire protection compounds, or antipyrines.

2.1.2. Materials, Items and Structures from Wood

Building logs from conifer and broad-leaved species should not be less than 14 cm thick at the top and 4 to 6,5 m long. Logs are used for hydraulic engineering structures, bridge elements, power transmission and communication lines, railway tracks.

Sawn timber is obtained by longitudinal cutting of logs planks, sleepers. By finish, sawn timber falls into clean-cut variety in which both edges have been cut throughout their length and non-trimmed variety in which the edges are not cut or cut less than half their length. Sawn timber for glued items and structures

(archs, beams, farms) should have a moisture content not more than 15%, and that for bridge span structures and other load-bearing constructions should carry not more than 25% moisture (pic. 1, 2).

Factory plank used for various building applications include platbands, plinths, finished floor boards, handrails for barriers, treads, window-sill board and exterior sheathing of house.

Floor materials include piece parquet, parquet boards, finish flooring boards, wood chipboards, wood laminates and wood fibreboards (pic. 3).

Wood chipboards are sheet materials manufactured by hot-moulding of wood chips, impregnated with polymers. In the course of hot-moulding, chips are compacted, and the viscous polymers harden, to cement the filler into a monolithic material. Wood chipboards are made of wood of conifer and broad-leaved species. Resistance of wood chipboards to water biological agents and fire is enhanced by treating chips with antiseptics and antipyrens.

Wood fibreboards are sheet materials composed of organic fibrous fillers (wood, reed, hemp) polymer-bonded together by hot-moulding. Culled wood is first cut into chips, than into fibres. Fibrous pulp is diluted with water and pumped to a reservoir for mixing with a solution of phenol-formaldehyde polymer (4-5% of the dry mass weight), hydrophobic additives, antiseptics and antipyrens. Fibrous pulp is pumped from the reservoir to a long mesh moulding machine for dehydrating and moulding the pulp into a continuous sheet, which is passed to a machine where it is cut into boards. By their average density, woodfibre boards are available in three kinds: semi-hard (not less than 400 kg/m^3), hard (not less than 850 kg/m^3) and extra-hard (not less than 950 kg/m^3). Soft boards are used for heat-insulating of walls and floors, semi-hard and hard boards are used chiefly for facing walls and the extra-hard ones, mostly for floors.

Veneer is manufactured by glueing together thin layers (thin sheets from 1,5 to 16 mm thick) of wood. Three kinds of veneer – glued, bakelite-treated and decorative – are generally used in building practice. In dependence of kind of glues glued veneer is subdivided into veneer of high water-resisting, medium and low water-resisting properties. By its jacket surface finish, veneer is subclassified into polished and unpolished types. Glued veneers of high water-resisting properties are used as load-bearing components (beams, arches, frames) of open-air structures that are protected against moisture by paint; for inside premises with air humidity less than 70% no-painting is required. Veneer of medium and low water-resisting properties is used for partitions and inside finishing of buildings.

Bakelite-treated veneer is manufactured from birch sheets not more than 1,5 mm thick. The faces of veneer are impregnated with alcohol-soluble or (and) water-soluble resins. Decorative veneer is made of thin sheets of birch, alder, lime, and is subdivided into two kinds of facing: veneer faced with colourless gluepainted film and veneer faced with film and decorative paper.

In building practice, decorative veneer is used for finishing interior walls partitions, panels, door panels and built-in furniture.

Fibrolite and arbolite are an artificial materials manufactured from wooden wool, waste wood or shavings bound together by mineral binding materials (Portland cement, gypsum, air-hardening or hydraulic lime). These manufactured articles are available in heat insulating, structural and pressboard varieties, which differ in average density. Heat insulating wares are used for insulating walls, floors, and roofs; structural variety, for filling walls partitions and roofs of frame buildings.

Xylolite is a hardened mass of sawdust and magnesian binder mixed with a liquor of magnesium chloride. Xylolite may contain such admixtures as asbestos, tripoli, quartz sand and dyes. If xylolite is intended for floors, it should have a plastic consistency. As soon as laid on a subfloor, the mass should be leveled and consolidated by vibration or tamping.

Industrial manufacture of xylolite slabs involves preparation of a harsh mass, which is then hot-pressed at a pressure. Magnesian binding materials also serve as a basis for a manufacture of foam and gas magnesite, which are highly efficient heat insulating materials. For this purpose, caustic magnesite, mixed with magnesium chloride liquor, is combined with foam or a gas forming agent.

Wood is used for manufacturing the following kinds of carpentry items: parts of doors, windows, partitions and panels (sheath, paneled, dead and glazed) for residential buildings and gates for industrial buildings (hinged, open, suspended and fixed, heat-insulated and non-heat-insulated). All types of carpentry items are made from conifer wood, whereas only interior doors and transoms for premises of relative air humidity of not more than 70% may be made from the broad-leaved species (beech, birch). Paneled doors, carpentry items and panels (of inside filling) are manufactured from waste of lag sawing, woodworking and veneer plants. Window sashes may also be produced from semi-finished materials with the use of water-resisting glues.

Wallpaper is a roll paper material with a printed pattern. It is used for decorative finishing of interior walls. According to application and service characteristics, wallpaper is subdivided into common, washable (moisture-proof) and sound-absorbing (felt) varieties. Wallpaper is available in a great variety of patterns and colours. By manufacture, pattern, colour and sill wallpaper is subdivided

into main body and borders. Patterns, colours and kinds of wallpaper can be readily combined to provide various decorative effects. Varnished wallpaper or one composed of layers of veneer backed by paper or fabric are used for special finishes. Once hanged, the veneer is polished to produce the effect of veneer-panelled wall. Lincrusta is a variety of wallpaper. It differs from linoleum by a paper backing, and from wallpaper, by a protective thin polymer film with a figured pattern. This kind of wallpaper is washable and may be painted with oil paints.

2.2. Polymers and Polymer-Based Materials

Polymer materials (plastics) are a wide group of organic materials based on natural or artificial high-molecular compounds (polymers). Plastics are complex substances. Their chief components are: a binder (a polymer), fillers (organic or mineral powders, fibres, cloths), plasticizers (which improve mouldability), curing accelerators, and dyes which are introduced to manufacture coloured plastics.

2.2.1. Composition and Properties of Polymeric Materials

Constructional polymers synthesized from the simplest substances (monoliths), are subdivided into two classes according to the production techniques:

- class A: polymers obtained by chain polymerization;
- class B: polymers obtained by polycondensation.

Class A polymers that find wide use in the manufacture of construction materials and items are as follows: polyethylene, polypropylene, polyvinylchloride, etc. Class B polymers include phenol-aldehyde, phenol-formaldehyde, epoxy polymers and other.

Structure of plastics is much affected by components other than polymers. This allows to subclassify plastics into no-filler, expanded, filler and composite varieties. No-filler plastics consist of a polymer, sometimes a dye, a plasticizer and a stabilizer. Expanded plastics consist, besides the above materials, of air or gas-filled cells produced by gas-forming or air-entraining substances. Constructional plastic is a polymer and a filler. There are powder, fibrous and laminated fillers.

Powder fillers – quartz powder, chalk, talcum and organic substances (ground sawdust) – provide plastics with valuable properties (heat resistance, acid resistance, etc.) and also improve hardness, increase durability.

Fibrous fillers – asbestos, wood and glass fibres – are widely used in the manufacture of plastics; they increase strength, reduce brittleness and enhance thermal resistance and impact strength of plastics.

Cloths and sheets fillers – paper, cotton and fiberglass cloths – make plastics very strong.

Plasticizers, dyes, lubricants, catalyzers and other substances are introduced into plastics along with fillers. Porous plastics are manufactured with the use of pore-forming agents.

With respect to heating, plastics are subdivided into thermoplastic and thermosetting varieties. Thermoplastic materials (polyethylene, polyvinylchloride and others) soften and become plastic, when heated, but harden again after cooling. These materials can be used to cast, draw and stamp various items. Their chief shortcomings are low mechanical strength and heat resistance. Thermosetting plastics change, when heated, into infusible and insoluble solid products, and irreversibly lose their ability to soften. These materials possess higher heat resistance and include aminoplasts and plastics based on polyester and epoxy resins.

Chief properties of plastics (physical and mechanical) depend on used polymer and used technology receipt of items.

Average density of plastics is $10-2200 \text{ kg/m}^3$. Plastics, as a rule, are poor conductors of heat, their coefficient of heat conductivity being $0,33-0,80 \text{ W/m} \cdot ^\circ\text{C}$, and that of foam and porous plastics, $0,06-0,028 \text{ W/m} \cdot ^\circ\text{C}$, and because of this they are widely used as heat insulating materials.

Plastics are not susceptible to corrosion, they resist attack by solutions of weak acids and alkalis. They are used for building chemical installations, sewage systems and for insulating storage tanks.

Polymers are the basic materials for the manufacture of adhesives for glueing plastics and with other materials, such as wood, metal, glass, fabrics. A valuable property of plastics is their high workability; they can be given various shape, by various techniques: casting, pressing, extrusion.

A large group of plastics can be welded to each other, which allows to manufacture complicated piping and various storage tanks. Plastics can be welded together by mere heating to a temperature between 150 and 250°C .

However, plastics have a number of shortcomings. Most plastics have a low heat resistance ($70-200^\circ\text{C}$). Plastics have a high coefficient of thermal expansion. They exhibit high creep. Plastics are susceptible to ageing, i.e., they disintegrate gradually, lose strength and hardness. Ageing of plastics is due to the action of light, air, temperature. When ignited, most plastics give off toxic substances.

2.2.2. Polymer – Based Building Materials

Polymer – based building materials are subdivided into:

- floor materials;
- materials for interior finishing of walls, ceilings and built – in furniture;
- synthetic glues and mastics;

- heat and sound insulating materials;
- roof, waterproof and sealing materials;
- sanitary equipment, piping and fittings;
- synthetic varnishes and paints;
- polymer-concrete and concrete-polymer constructions (pic. 4,5,6).

Floor materials

Polymer materials find an extensive application in the building of floors. They are resistant to abrasion, have a low heat conductivity and water absorption, sufficient hardness and strength; they fail to swell when moistened, readily take on varnishes and paints and meet all the requirements for floors.

Floor materials fall into three groups: roll (linoleum), tile and seamless floor varieties.

Floor roll materials manufactured from various polymers and fillers, are composed of plasticizers, pigments and process additives. According to the kind of polymer, floor roll materials are subdivided into glyptal (polyester), polyvinylchloride, colloxilin, rubber (relin) varieties. As to the structure, they fall into the following types: with and without strengthening or heat and sound insulating backing; single- and multi-layer and carpet coverings with smooth, creased and nappy surfaces; single – and multi-coloured textures.

Linoleums are manufactured either by the rolling-and-calendaring (no-backing linoleum) or by the coating technique.

Glyptal linoleum lowers the heat conductivity of floors even without special thermal insulation and is used for floors of both residential and civil buildings.

Polyvinylchloride (PVC) linoleum is available with and without a fabric backing, the latter being a single-, double-, or multi-layer material. The backing of this linoleum may be of cord, half-cord, jute and jute-hemp cloth. Besides, linoleum is produced in heat and sound insulating varieties on a felt or porous backing. Polyvinylchloride linoleum is very strong, abrasion-resistive, not susceptible to decay, has low thermal conductivity and is highly hygienic.

Vorsolin, a heat-and-sound insulating floor covering, is a nonwoven two-ply material, where the top ply is a napped or plain pile of synthetic single- or multi-colour yarn and the bottom ply, a PVC film backing. It is used for covering reinforced concrete floors or subfloors in room-sizes in residential and public buildings of improved acoustic and heat-insulating properties.

Nitrocellulose linoleum is produced on a colloxilin backing and with the use of plasticizers, fillers and dyes. This linoleum should be laid on a hard smooth bed with the use of mastic. It should not be used for theatres, places of entertainment and children's institutions.

Rubber linoleum (relin) is a two-layer roll material with a wear-resistant decorative top layer. Relin manufacture involves crushing of waste rubber, preparation of bitumen-rubber mixture for the bottom layer; calendaring of the bitumen-rubber mixture into sheets; preparation of a coloured rubber mixture for the top layer; calendaring of the coloured rubber mixture into sheets; doubling of the two layers; cooling, ageing, cutting to specified lengths and widths, inspection and packing. Relin is intended for floors in dwelling, public and industrial buildings of high atmospheric moisture content.

In current building practice, floors are frequently being made with tiles, manufactured from polymers, plasticizers, fillers and pigments.

Tile floors are wear resistant durable and chemically resistant. They should be glued onto a perfectly levelled concrete, asphalt or xylolite bed by special adhesives or mastics. By the kind of raw materials for their manufacture, floor tiles are subdivided into rubber, phenol polyvinylchloride, coumarone, and rubber varieties.

Floor tiles are available in a wide range of types: in shape, they are square, rectangular and figured; in design, single- and multilayer, with rectangular and groove and tongue edges; in colour, single- or multi-coloured; and in texture, smooth or riffled. The manufacture of the tiles involves preparation and proportioning of raw materials, thorough blending in a mixer, rolling, calendaring, tile stamping in a press, inspection and packing of finished tiles.

Tiles are used for floors in dwelling, public and industrial buildings.

Rubber tiles are made of waste rubber. They are highly wear and chemically stable and have good dielectric properties. Rubber tiles show not only high bending and compressive strengths, but also an excellent impact strength, which is a major advantage in concern of working conditions in industrial buildings. Rubber tiles are usable for floors of workshops at chemical plants, laboratories, power stations, etc.

Monolithic seamless floors from polymers are most hygienic and convenient in service, and have a high wear resistance. Seamless floors are made from polymer binding, mineral fillers. By the kind of polymer binding seamless floors are divided into three types: polyvinylacetate, polymer cement and plastic concrete.

Polyvinylacetate mastics consist of a binder, a filler, a dye and water. Polymer concrete seamless floors are manufactured of polyvinylacetate or latex emulsion, Portland cement, sand, marble or granite crumbs and mineral pigments. By consistency compositions it may be plastic-concrete (laid with the aid of laying machines or vibrating devices) and fluid-mastics (sprayed or poured). Polymer concrete compositions exhibit high adhesive properties. They provide a strong bond with the bed and have high mechanical strength. Polymer concrete

can be used for residential, public and industrial buildings and installations. Polyvinylacetate mastics should not be used in premises with high atmospheric moisture, in industrial buildings where there is a risk of impact loads and in unsprung transport vehicles.

Plastic facing materials for walls

Plastic facing materials surpass all other finishing materials in ornamental quality, variety of patterns, richness of colours and hygienic properties.

Interior walls and ceilings are generally finished with roll, sheet and tile plastics. Roll materials for interior finishing of premises are made of polymer plasticizers, fillers, pigments, with or without a backing, which may be of paper, cotton and glass cloth or any other suitable material. Polyvinylchloride film with an adhesive layer is used for finishing interior walls of dwelling and public buildings, washrooms, corridors, partitions, door frames and built-in furniture. Paper-backed finishing polyvinylchloride film is used for finishing interior walls of dwelling, public and industrial buildings.

Lincrust is a roll material composed of a paper backing covered by a layer of plastic mass. This material is water and decay resistant, withstands high mechanical stresses, does not fade in sunlight. It is used for finishing walls, partitions and built-in furniture in dwelling, public and industrial buildings.

Imitation leatherette is used for finishing walls, partitions and furniture in dwelling, public and industrial buildings.

Sheet materials for interior finishing of buildings are manufactured in the following varieties: decorative paper laminate, decorative veneer wood fibre and chipboards with decorative polymer surface, and also profile polymer coloured sheet of 2-3 m long.

Decorative paper laminates are sheet material obtained by hot moulding of special papers, impregnated with polymers. Decorative paper-plastic laminate is manufactured 1-3 m long, 600 or 1000 mm wide and 1-5 mm thick. This material is made in single colour and with textured surfaces, imitating valuable species of wood or stone. They withstand heating to 120°C, retain luster in boiling and are sufficiently waterproof. They belong to the group of combustible materials, but if the paper is impregnated with antipyrens, laminates of reduced combustibility are obtained.

Wood laminates are sheet material from wood veneer impregnated with polymers and glued together by pressure thermal curing. These materials possess a sufficiently high heat resistance and a low heat conductivity; they withstand attack by oils, organic solvents and atmospheric agents and lend themselves readily to mechanical working. Wood laminates are used in residential, public and industrial buildings as a finishing-and-structural material. Wood chip

and wood fibreboards may be faced with paper, impregnated with polymers. Facing with paper allows to manufacture structural parts of a great variety of surface colours, patterns and textures. These items are used for interior facing of walls, manufacture of decorative panels, and covering of ceilings.

Facing polymer tiles are superior to any other facing materials in decorative properties (variety of colours and patterns). These tiles are manufactured from polystyrene. To enhance heat resistance and reduce the cost of tiles, powder fillers (talcum, kaolin, etc) may be introduced. Polystyrene tiles are resistant to 10% solutions of acids and alkalis, have high vapour and water resistances, high strength and good dielectric properties. On account of their combustibility, they cannot be used for facing fire-resistant structures and heated surfaces.

Polystyrene tiles are employed for interior finishing of dwelling, public and industrial buildings of high hygienic requirements, and high temperature and moisture conditions (bath-rooms, wash-rooms, hospitals, canteens, and shops).

Polymer constructional materials

One of the characteristic properties of polymer constructional materials with respect to those generally used in building practice is their small bulk density, high strength, good thermal, sound- and waterproofing properties and immunity to attack by chemical substances. Structural polymer materials are mostly reinforced plastics such as glassfibre plastics, organic glass, sheet vinyl plastics, polymer-concrete and concrete-polymer.

Glassfibre plastics are manufactured by laying stretched glass fibres parallel to one another and by applying a binder simultaneously. The binders are modified phenolfor maldehyde, epoxyphenol and other polymers.

Glassfibre plastics based on chopped glassfibre are obtained by spraying or pressing glassfibre mats. Spraying technique. Chopped glass fibres 25-50 mm long are mixed with a polymer binder and applied in a thin layer upon the surface of a mould with the aid of a spraying gun. When cold-hardening polymers are used, items are moulded at the room temperature, whereas moulds are heated to binder hardening temperature when hot-hardening polymers are used. Glassfibre plastics are used for making transparent walls and partitions, light-transmitting cold and semi-cold openings in workshops with chemically aggressive atmosphere (in combination with a translucent material).

Organic glass (polymethylmetacrylate) is a highly transparent, light-resistant, relatively lightweight material. It neither becomes dull nor yellow with time, does not embrittle, withstands attack by atmospheric agents. Organic glass is elastic and retains this property even at low temperatures, when its bending and tensile strengths increase, but it does not become brittle. Organic glass is 7 times stronger than silicate glass.

Organic glass is used for translucent walls and partitions of single- and double-layer vertical openings and overhead lighting domes of public and industrial buildings and greenhouses.

Polymer-concrete constructions are manufactured from hot mixture polymer-binding materials with mineral fillers.

Concrete-polymer constructions are manufactured by impregnation of concrete (reinforced) constructions with a hot polymer solution.

Plastic pipes are made by extrusion. Plastic pipes are widely used in the installation of various industrial piping, water supply conduits, sewer systems, petroleum pipelines, irrigation facilities, etc. The ones mostly used are polyvinylchloride, glassfibre plastic and organic glass pipes; then come pipes from polypropylene and phenolite. Polypropylene pipes easily withstand temperatures up to 100°C, whereas phenolite pipes show good stability in chemical media. Plastic pipes are more durable than metal ones, weigh less and have a lower heat conductivity, high water, dielectric and chemical resisting properties. Cost and maintenance of plastic pipes are cheaper than for metal pipes. A shortcoming of plastic pipes is their poor heat resistance; e.g., polyvinylchloride pipes are unsuitable for transferring liquids with temperatures above 60°C.

Plastics are used to manufacture various sanitary ware. They are pleasant to the eye, water resistant, lightweight, strong, corrosion resistant, and immune to the action of acids and alkalis. This type of items includes, washing racks and others.

Honeycomb plastics are characterized by cavities of regular geometric shape. These plastics are manufactured by hot moulding of polymer impregnated paper, fabrics, veneer.

The materials are corrugated in a press. Corrugated sheets are coated with polymer, stacked, and then glued together into blocks at normal or high temperature, and pressed.

Physical and mechanical properties of honeycomb plastics depend on the honeycomb material, kind and quantity of polymer and size of cells.

Honeycomb plastics are used mainly as a filler of three-layer panels. Heat insulating properties of honeycomb plastics are enhanced by filling cells with crumbs of heat insulating materials.

Rigid foam plastic consists of a system of isolated, non-communicated cells, filled with gas or a mixture of gases. Foam plastics can be made of various bulk densities (60-220 kg/m³) depending on the quantity of the gas-forming agent. Foam polystyrene or polyvinylchloride plastics are used for making three-layer panels for walls and roofs of dwelling, public and industrial buildings. Three-layer panels are of glued design, the exterior layers being glassfibre plastics, asbestos-cement, aluminium and other materials. Foam polyurethane is used also in the form of shells intended for insulating piping of cold and hot water supply.

Slender and tubular items are manufactured by means of an extruder from polyvinylchloride, plasticizers, fillers and dyes in a great variety of profiles and colours for various applications. Plinths, handrails, bars and structural elongated materials (angles, T-bars, pipes) can be listed among such items.

All these items must satisfy the following general requirements: a uniformly glazed or dull finish, lack of scratches, cavities, cracks and peeled surfaces; homogeneous structure and uniform profile and colour, which is resistant to the action of air, light and water.

Polymer-based glues, mastics and paints

Polymer-based glues and mastics are used for glueing together cast, laminate and fibrous, materials and elements of parts and structures manufactured from various building materials (wood, metal, concrete and others). Mastics and glues for securing finishing materials and items are adhesive paste-like compositions consisting of an adhesive base, e.g., polymers, solvents, plasticizing compounds, fillers, diluents, and sometimes hardeners. Glues and mastics intended for fastening finishing materials and items are subdivided into two groups; one is used for glueing floor coverings and slender and tubular items, and the other, for securing materials in the finishing of walls, ceilings and built-in furniture. By the kind of adhesive substance and mastics intended for finishing materials and items are divided into bitumen, polymer, caoutchouc, nitrocellulose and casein varieties.

Mastics for glueing finishing materials should have good adhesive properties, withstand temperatures up to 50-60° C, be easy to apply and spread in a uniform layer 0,3-0,5 mm thick. Mastics should be resistant to biological agents, homogeneous, odourless.

The mastic is applied by spraying and pneumatic guns.

Building structure glued joints are sufficiently strong at temperatures from -30 to +60° C and sometimes down to -60° C. Structural glues are stable to the action of water and its vapours.

Varnishes and paints are natural, artificial or synthetic materials applied in a thin (60-500 µm) layer upon a surface to be protected and forming solid impermeable films bonded strongly to the surface. These films should be sufficiently strong and highly durable both in physical and mechanical properties and in decorative qualities. Varnishes and paints should be harmless to the material of the item being protected and the living organisms. Coating materials are subdivided into paints, varnishes and auxiliary materials. Paints are intended to provide an opaque coloured decorative and protective coating, and the varnishes, a translucent covering and a final decorative finishing of painted surfaces. Auxil-

iary materials: putties, priming compounds, used to prepare surfaces for painting and varnishing. Dissolvent used for latter to a working consistency in polymer varnishes and paints. Diluents (water, oil) used for latter to a working consistency in water-emulsion and oil paints accordingly.

Constituents of varnishes and paints are subdivided into pigments, fillers and vehicles. Pigments are intended to give paints desired colours. Pigments are coloured finely ground mineral or organic substances, insoluble in water and organic solvents. Metal powders (aluminium, bronze) may also be used as pigments. Pigments fall into natural or artificial and mineral or organic categories. Each pigment possesses characteristic colour and properties. The general properties of pigments are covering power, colouring capacity, fineness, light and fire resistance, chemical stability, resistance to atmospheric agents.

Covering power of pigments is characterized by its consumption per 1m^2 of the surface being painted.

Colouring capacity is the ability of pigments to transmit their colour when mixed with white, black and blue pigments.

Fineness of pigments greatly affects both the covering power and the colouring capacity. The finer the pigment, the greater are these properties.

Fire resistance of pigments is their ability to withstand high temperatures without deterioration and change in colour. Organic pigments are not fire resistant, whereas mineral pigments react differently to temperature fluctuations.

Anticorrosive power is the ability of pigments, in combination with binder and fillers, to protect concrete and metals against corrosion. For example, iron minium and lead white have good anticorrosive properties. Natural mineral pigments are used for preparing lime, cement and glue paints, putties and coloured building mortars. Metallic powders (aluminium, bronze, gold dust) are usable for decorative painting of metals.

Organic pigments are used to tint paint compositions on various binders. However, their light resistance is relatively low. Fillers are insoluble mineral substances, mostly white, which are added to paints to save pigments and impart particular properties to these materials, e.g. high strength, acid resistance, fire resistance, low deformation. By the kind of vehicle, painting compositions are subdivided into oil, glue and polymer paints.

The vehicles in oil paints are linseed oil and oil varnishes. They form the body and enhance film-formation in varnish or paint coats. In glue paints, the vehicles are animal, plant, artificial and synthetic glues, and in polymer paints, respectively polymer.

Natural drying oils are vehicles which harden in thin layers to form strong and elastic surface coats. Artificial or synthetic drying oils are film-forming compositions that contain no drying oils, but are capable of replacing them in

painting jobs. Drying oils are used to dilute paints, to manufacture prime coats and putties, to coat wood, plasters and other surfaces. Drying oils should dry in thin layers within 24 h of application at a temperature of 20°C and should not peel off. Dryers (siccatives) are added to hasten the hardening of drying oils.

Oxol drying oil mixture is a substitute of natural drying oil; it is manufactured by thickening a mixture of linseed or hempseed oil by air-blowing in the presence of siccatives and subsequent addition of solvents (white spirit, naphtha-solvent). Oxol drying oil mixture is used for diluting pigment pastes for exterior and interior works.

Artificial synthetic drying oils, in contrast to natural or semi-natural ones, contain not more than 35% of vegetable oils. Of the many artificial drying oils, widely used are glyptal, shale, syntol, etynol (varnish) and coumarone-indene ones. These vehicles are used for manufacturing quality painting compositions for exterior and interior finishing of metal, wood and plaster.

Clues are employed as vehicles in glue and water painting compositions, for glue primers and putties, and as stabilizers in the production of water-colour emulsions. There are animal (hide, lone, casein), plant (dextrin), artificial glues. Artificial glue is a solution of artificial resins in water and polymer glues. Polymer glues are polymer synthetic substances of high glueing power, manufactured from polyvinylacetate resin. This glue is used in the form of water-and-alcohol solutions and of water-diluted emulsions for glueing film materials and wallpaper.

Diluents are intended to dilute pigment pastes or dry mineral paints. In contrast to solvents, diluents contain a film-forming agent in amounts sufficient to obtain a quality varnish or paint coat.

Emulsion diluents are water-in-oil emulsions. They are used for the manufacture of primers and diluting pigment pastes for oil paints, this contributing to a more economical use of weakly polymerized drying oils and synthetic resins.

Emulsion diluents provide poor quality coats, and therefore they find only a limited application.

Thinners are liquids intended to adjust the consistency of paint for application. The thinner for glue water-emulsion colours is water. Common thinners are turpentine, coal solvent, white spirit and others.

Varnishes are solutions of resins in volatile thinners. The latter evaporate from the varnished surface, leaving a thin resin film which gives the surface luster and hardness. There are two groups of varnishes: oil-resin, oilless synthetic.

Paint compositions are subdivided into oil paints and varnishes, volatile resin (polymer) varnishes, enamel and paints, water-emulsion colours.

Oil paints are mixtures of pigments and fillers, ground in paint grinders together with plant drying oils. Oil paints are available both as pigment pastes (to be diluted with drying oil to painting consistency prior to use) and as ready-to-use paints. Oil paints are used for exterior and interior painting of metal, wood, plaster and concrete.

Oil paints diluted with drying oils of vegetable origin should be used only on dry plaster and hardened concrete.

Enamel paints are suspensions of mineral or organic pigments and of synthetic or oil varnishes. The widely used enamel paints are alkyd, epoxy and urea-formaldehyde varieties. Enamel paints possess good light resistance, anti-corrosion properties, dry rapidly. They are used for painting metal, wood, concrete and plaster of interior and exterior surfaces.

Emulsion (latex) colours are pigment emulsions or polymer dispersions in water. Emulsion colours that find application in building practice are as follows: polyvinylacetate and acril emulsions are a water emulsion of polyvinylacetate or acril with a pigment. They are manufactured at plants and supplied in paste form, being diluted with water prior to use; they are usable for exterior and interior painting of concrete, plaster and wood and for sheet materials – lincrust and cardboard.

Painting jobs call for a number of auxiliary materials, such as putties, primers. Putties are paste-like compounds used for sealing glazed window sashes, grooved joints and ridges of sheet steel roofs.

Employed for sealing window sashes are chalk, lead-minium, lead white and naphthene putties, composed of natural drying oil, ground chalk, minium or lead white. When installing a roof from sheet steel, a roof putty is used which consists of natural drying oil, chalk and iron minium, or of a Kuzbass varnish putty made of Kuzbass varnish, iron minium and ground chalk.

Putties possess good water-resisting properties and plasticity.

Primers are paint compositions consisting of pigments or dyes, extenders and binders. They are available in two kinds: primers for water paints and primers for oil and synthetic paints. Water paints require copper sulphate primer or boiled soap, soap and glue. Primers for oil paints are generally diluted with drying oil or a thinner.

In finishing jobs, primers are employed for reducing the porosity of surfaces to be painted, to reduce the consumption of expensive paints and improve the appearance of coatings, to enhance anticorrosion protection of metallic surfaces, to provide prime coats on wood and other surfaces to be varnished and to provide stronger bonds between the paint and the supporting surface.

2.3. Bitumens and Bitumen-Based Materials

Bitumen is a complex mixture of high-molecular hydrocarbons and their non-metallic derivatives, its physical and mechanical properties varies with temperature. By consistency (at 18°C), bitumens are subdivided into solid, semisolid and liquid.

Chief properties of bitumens are water impermeability, resistance to acids, alkalis, aggressive liquids and gases, adhesiveness to rock, wood, metals, ability to become plastic when heated and to thicken rapidly when cooled. In the building materials industry and practice, bitumen finds application for preparing asphaltum concretes, for manufacturing roof, waterproofing and steamproofing materials and sheet items, mastics, emulsions, varnishes and paints (pic. 7).

According to the origin of materials bitumens fall into natural and petroleum ones. Pure natural bitumen occurs very rarely. Rocks (limestones, sandstones, soils) impregnated with bitumen are found more frequently.

Natural bitumen originated from petroleum as a result of a slow spontaneous distillation of lighter and medium fractions and of polymerization and oxidation.

Petroleum has accumulated in the top layers of the earth's crust through migration, filling pores and cavities of rocks and impregnating them over the millennia under the action of high temperature and pressure.

Natural bitumen is a black or dark-brown organic substance which, when heated, gradually softens and passes to liquid state, but solidifies, if cooled. Natural bitumen is insoluble in water, but dissolves readily in organic solvents. Structure of natural bitumens, their physical, chemical and mechanical properties are close to those of petroleum bitumens.

Natural bitumens may be extracted from bitumen rocks by boiling in kettles or dissolving in organic solvents.

Bituminous limestone and dolomite rocks are used as a fine powder (asphaltum powder) to manufacture asphaltum mastic and asphaltum concretes.

Petroleum bitumens are products of processing of crude petroleum and its resinous residues. By viscosity petroleum bitumens are divided into solid, semi-solid and liquid varieties, and by processing techniques, into residual asphaltums, and extracted bitumens. Petroleum bitumens are poured while still hot into metal containers and shipped to consumers after cooling.

2.3.1. Chief Properties of Bitumens

Physical and mechanical properties of bitumen should describe the material from the standpoint of its molecular structure and the combination of its inherent properties.

Solid and semi-solid bitumen fall into marks, the division being based upon viscosity, plasticity and behavior with respect to temperature.

Viscosity is the property of material to resist the mutual motion of particles under the action of external forces. Viscosity of bitumen depends greatly on its temperature. At lower temperatures, viscosity of bitumen is great and it acquires the properties of a solid body; as temperature rises, viscosity decreases and bitumen passes into liquid state. Viscosity of bitumens is evaluated in conventional units of hardness, which is the depth of penetration of a needle under the weight of 100 g applied for 5 s at 25°C and 0°C. Depth of penetration is determined by means of a special apparatus the penetrometer. It is expressed in degrees (1° = 0,1 mm) and designated as Π_{25} , the subscript indicating the temperature of material during testing.

Ductility of viscous bitumens is characterized by extensibility which is found with the aid of a ductilometer. Bitumen test specimens have a standard “figure 8” shape and size. Ductility of bitumen is measured by the distance (in cm) to which it will elongate before breaking when two ends of a briquette specimen of the material are pulled apart. This test is carried out at a speed of 5 cm/min and temperatures of 25° C and 0°C.

Similar to viscosity, ductility of bitumens depends on temperature, group composition and nature of structure. Plastic properties are observed in bitumens that contain a considerable amount of resins, an optimum quantity of asphaltenes and oils. Viscous bitumens, containing solid paraffins at low temperatures, are not very ductile.

A third major property of bitumens is their softening point, which is determined in an apparatus called “ball and ring”. A brass ring 16 mm in diameter and 6,4 mm high is filled with bitumen, and a ball 9,5 mm in diameter and a mass of 3,5 g is placed upon the latter

Softening point is the temperature of water in the apparatus when the bitumen softens and the ball sinks to the bottom shelf of the frame.

Along with the chief properties of bitumens, such as viscosity, extensibility and softening point, which serve as a basis for their grading, bitumens are described by a number of other characteristics, e.g. stability of bitumens in water which governed by the content of oils, resins and asphaltenes; cohesiveness which is characterized by intermolecular bond strength; adhesiveness of bitumens with respect to stone materials which depends on physical and chemical properties of bitumens; weather resistance of bitumens, i.e., ability to withstand the action of atmospheric agents in elements of structures.

2.3.2. Bitumen-Based Materials

In the building practice bitumen find application for preparing protective varnishes and paints, emulsions mastics, pastes, asphaltum concretes, for manufacturing roof, waterproofing, steamproofing and sealing materials and items.

Varnishes and paints based on bitumens and asphalts are solutions of bitumens, asphalts and vegetable oils in organic thinners (benzene or gasoline). Bitumen varnishes and paints are usually black or brown, they are resistant to acids and alkalis and used for anticorrosion steam- and waterproofing coats, finishing stoves, painting gas ovens and other surfaces.

Emulsions are disperse systems composed of two immiscible liquids, one of which is finely dispersed throughout the body of the other. In similar systems, distinction is made between the dispersion (continuous) medium and the dispersed phase which is distributed in the former. Bitumen emulsions are disperse systems in which water plays the part of the dispersion medium, and bitumen the dispersed phase. To obtain emulsions, bitumen should be finely dispersed, their particles uniformly distributed in water and prevented from sticking together into larger aggregates. An emulsion is formed and stabilized by introducing special emulsifiers – surfactant substances or finely dispersed solid powders, which, on one hand, lower the surface tension between bitumen and water and thus contribute to finer dispersion, and on the other hand, charge the particles electrically so as to prevent their flocculation. Bitumen emulsions are obtained by mechanical dispersion with the use of extra-high-speed rotary mechanisms (homogenizers) into which a mixture of molten binder and water with an emulsifier is fed through a slot between the disks and the casing of the machine. Rapid rotation of disks causes bitumen to disperse in water under the action of centrifugal forces. An emulsifier, present in water coats particles of the binder and thus stabilizes them. Acoustic dispersing means have lately found use in preparing bitumen emulsions.

The quality of bitumen emulsion, characterized by its disintegration rate, depends on the properties of emulsifiers and the fineness of the emulsion. Emulsions for mixing with fine materials should not disintegrate until fully combined with the latter, whereas those used for treating moist surfaces should be stable in water. Bitumen emulsions, once applied to a surface, should rapidly give off bitumen in the form of a thin solid film, which should not turn again to emulsion under the action of water.

Emulsions are used for making water- and steam-proof coatings, priming surfaces in preparation for waterproofing, glueing piece and coil materials and making the surfaces of items hydrophobic.

Emulsions are stored in metal containers in closed premises at a temperature not below 0°C; containers should be clean, as impurities may cause rapid disintegration of emulsion. Emulsions should be transported in barrels or tanks.

Bitumen paste is employed to protect water- and steam-proofing coatings, to prime surfaces before they are insulated, to fill roof joints and to prepare cold mastics, in which it plays the part of a binder.

Bitumen pastes are prepared from bitumen, water and emulsifiers. The latter are nonorganic finely dispersed mineral powders, containing active colloidal particles smaller than 0,005 mm which are added to water to produce pastes. Common emulsifiers are lime, clay. Most water-resisting pastes are made with lime emulsifiers.

Mastics are produced from organic binders and fillers. The latter are used for raising thermal resistance, decreasing low-temperature brittleness and consumption of binder. Mastic fillers fall into powder, fibrous and combined (a mixture of powder and fibrous fillers) types. The powder fillers are lime, dolomite, quartz, talcum and many others, and the fibrous fillers are chrysolite asbestos, asbestos dust, and short-fibre mineral wool.

By the kind of original binder, mastics are subdivided into bitumen, bitumen-polymer (including bitumen-caoutchouc), and rubber-bitumen varieties.

By laying technique, mastics fall into hot and cold types. Hot mastics should be preheated before use by temperatures more 70°C. Cold mastics are used without preheating at ambient temperatures down to 5°C. Cold mastics are manufactured on diluted binder and bitumen pastes.

Hot mastics are divided by application into glueing, roofing-and- waterproofing varieties. Glueing mastics are intended for glueing soft roof covering in multilayer roofs and for waterproofing.

Roofing- and- waterproofing mastics are used for glueing, and also for manufacturing roofing sheets and waterproofing. Glueing and roofing-and- waterproofing hot mastics should be solid at $18\pm 2^\circ$ C, homogeneous, free from visible inclusions and impurities and carry no filler particles not coated with bitumen. Waterproofing hot mastics should not expand in volume under vacuum; mastic should practically absorb no water under vacuum.

Cold mastics at temperatures of $18\pm 2^\circ$ C should be mobile, homogeneous, free from visible inclusions. Mastics prepared with diluted binder are used for glueing roll roofing, building protective coverings and water-and steam-proofing.

Cold mastics on bitumen pastes are prepared by mixing bitumen pastes with mineral fillers and antiseptics, the diluents being water. Cold mastics on bitumen pastes are employed for making cast and plaster waterproofing, filling expansion joints and building roofs in the southern part of country.

Asphaltum concrete is an artificial material manufactured by compacting a special mixture composed of crushed stone (gravel), sand, mineral powder, and bitumen. It is generally used in road construction. Depending on the temperature of laying and compaction in a road covering and the viscosity of the bitumen, asphaltum concretes fall into:

- hot concretes prepared on viscous bitumens at temperatures of 140-180°C and laid in the covering at a temperature not lower than 130°C; formation of concrete structure is practically completed during compaction;
- warm concretes prepared on bitumens of a lower viscosity at temperatures of 90-160° C and laid in the covering at a temperature of 30-100°C; structure formation is practically over before compaction;
- cold concretes prepared on liquid bitumens and laid in the covering at temperatures in the 80-120°C range, for 20-30 days. Classed with cold concretes are asphaltum concrete mixtures on bituminous emulsions that are laid at normal temperatures.

By maximum size of mineral grains, asphaltum concrete is subdivided into coarse-grained (maximum size of grains 40 mm), medium-grained (25 mm), fine-grained (15 mm) and sand-grained (5 mm).

By structure characteristics, asphaltum concrete falls into a dense variety of an overall porosity of 3-5% and a large-poured variety of 5-10% porosity.

Coarse-grained asphaltum concrete is employed for making base courses of roads.

Medium-grained asphaltum concrete is used for single layer coverings and for top layer of two-layer roads.

Fine-grained asphaltum concrete has a sufficiently high resistance to mechanical and atmospheric actions, and is employed in wearing courses of high-intensity traffic high-ways and for top courses of two-layer roads.

Sand asphaltum concrete has a high plasticity and is readily compacted, its chief applications being floor coverings in industrial building workshops, sidewalks and light-traffic roads.

Roofing, water-and steam-proofing materials

Steam-proofing materials used to protect exterior walls structures against the action of vapour moisture. Roofing, water-and steam-proofing materials based on bitumens binders, are subdivided into coiled and sheet materials; emulsions and pastes, mastic and piece items concretes, varnishes and paints. By kind of binders and their mixture, roofing, water- and stem- proofing materials fall into:

- bitumens, composed of petroleum bitumens or alloys of petroleum and natural bitumens;

- rubber-bitumen materials manufactured by combined processing of petroleum bitumens and waste rubber;
- polymer-bitumen, composed of petroleum bitumens and polymer.

Bituminous roofing and waterproofing materials, widely employed in building practice, are generally of the following two types: ones prepared by impregnating special cardboard or glass cloth (CT) or polymer cloth (ИТ) with petroleum bitumens or bitumens-polymers compounds and subsequently coating it with a compound of higher melting temperature and a granular material (gravel or sand); other fabricated by calendaring thermally and mechanically processed mixtures of binders and additives into sheets of prescribed thickness.

Impregnated roll materials are subclassified by the kind of binder into bitumen (Б) and bitumen-polymer (БП) varieties.

By structure, roll materials are subdivided into coated and non-coated types, but also into backing and no backing.

Backing roll materials prepared by impregnating roof cardboard or glass or polymer cloths with soft bitumen or bitumen-polymer, subsequently coating it on one or both sides with high-melting bitumen or bitumen-polymer varieties and finally facing it with finely-ground mineral powder (П, М), mica (У), coloured mineral granules (К), metallic foil (МФ) or polymer film (ИИИ). Second side facing it with finely-ground mineral powder or polymer film. Whereas the figures give the mass in kg of 1m² roll material. For example: К-ИТ-БП-К/ИИИ-4,0.

Roofing and waterproofing roll materials with no backing are subdivided, by the kind of binder, into rubber-bitumen, bitumen-polymer and polymer varieties. Mostly used are rubber-bitumen materials. These materials are durable, elastic, resistant to decay and do not absorb water. They are manufactured from materials containing caoutchouc or crushed rubber in combination with bitumens, coal resins or bitumen-polymer binders, mineral fillers (powder or asbestos fibres) and a plasticizer.

These materials are used for anticorrosion protection of underground metal piping but also as a glued-on material for waterproofing buildings and installations, and as a component of two- or three-play sloping flat roofs built of bitumen and hot-process mastics.

Piece waterproofing items

Piece waterproofing items are of three kinds: waterproofing asphalt slabs, waterproofing stone and prefabricated concrete items.

Waterproofing asphalt slabs are manufactured by covering pre-impregnated fiberglass or metal mesh by a hot-process waterproofing mastic or sand asphalt concrete mastic or by press-moulding hot-process waterproofing

asphalt mastic or sand asphalt concrete mixture. Slabs are either reinforced or non-reinforced. Non-reinforced slabs are made 90-100 cm long, 50-60 cm wide and 1-2 cm thick, whereas reinforced slabs are 100-120 cm long, 75-120 cm wide and 2-4 cm thick.

Waterproofing asphalt slabs are used for glued-on waterproofing work and filling of deformation joints. They may be employed during the cold season.

Waterproofing stones are manufactured by impregnating artificial or natural porous materials (brick, concrete, tuft, chalk, etc) with bitumen or coal tar products to a depth of 10-15 mm. Stones should be waterproof. They are employed for making waterproof brickwork and lining with use of cement and asphalt mortars.

Prefabricated waterproofing reinforced concrete items are manufactured by impregnating prefabricated reinforced concrete elements (piles, slabs, sections of pipes, tubings, etc.) with organic binders to a depth of 10-15 mm. These items are used for anticorrosion waterproofing of installation exposed to simultaneous action of impact loads and mineralized water.

Sealing materials are used for filling exterior joints between elements of prefabricated structures of buildings and installations. Depending on the purpose of the sealing joint, sealing materials are used for thermal insulation, waterproofing, sound insulation and airproofing. Sealing materials are generally divided into elastic liners and sealing mastics.

Elastic liners are manufactured in the form of porous or monolithic braids of various shapes. They are put into place dry or on special glueing mastics.

Paroizol is a porous elastic sealing material intended for sealing exterior joints between elements of prefabricated structures of buildings and installations. Paroizol may have open pores on the surface for use in combination with cold-process izol mastic, but may have a protective ozone-resistant film.

Sealing mastics are subdivided into packing and protective types. The packing mastics are manufactured by mixing high-molecular polymer or bitumen, rubber and filler.

Sealing and protective coverings of joints are made with mastics based on polythiophene caoutchoucs (thiocol).

Roofing, waterproofing, steam-proofing and sealing materials and items from organic binders should be stored in original packing, protected against damage, atmospheric action and contamination. In transit, particular care should be taken to protect them against atmospheric agents.

Chapter 3. MINERAL BUILDING MATERIALS

Building materials are widely used in construction as slabs for walls and foundations of buildings, as facing. Wares are used for exterior and interior walls, and floors of buildings, for roads, sidewalks, and also as neat-insulating, water-insulating materials. All building materials are generally classified according to their purpose (constructional, foundry facing, acoustic, heat-insulating and others), and kinds of materials (natural stone, ceramic, glass, polymers and others). As it is known, the building materials can be organic (wood, polymers, bitumen) and mineral (stone, ceramic, glass, metal); Organic materials are obtained from wood, oil, gas. Mineral ones are obtained from mineral rocks (sand-glass, clay-ceramic, ore-metal). The shape of building materials may be friable (sand, crushed stone), leafy (glass, metal, little and big blocks from natural stones, ceramic and concretes) and liquid (glue, colours).

By the kind of original raw material, mineral building materials are subdivided into natural rock, ceramic, materials from mineral melts, metallic items and artificial stone.

3.1. Materials and Items from Natural Rock

The earth's crust is composed of rocks.

Rock is a mineral mass of a more or less uniform composition, consisting of a single (monomineralic) or of several (polymineralic) minerals. Monomineralic rocks may be exemplified by quartz sand, chemically pure gypsum, magnesite, and the polymineralic ones, by granite, basalt.

A mineral is a body, homogeneous in chemical composition and physical properties. Minerals are products of physical and chemical processes occurring in the earth's crust.

Owing to their universal occurrence and various physical and mechanical properties, natural rock materials are widely used for building purposes. They are used as mined (gravel, sand) or processed mechanically (crushed, sawn, dressed, polished) to crushed stone, plates, piece stones, various architectural and decorative items (pic. 8-12).

Rocks are the main source material for the manufacture of mineral binding materials, such as gypsum, lime, cements, and of artificial rock materials: brick, glass, items from concrete and mortars.

3.1.1. The Genetic Classification of Natural Rocks

The study of the properties of natural rock materials may be greatly facilitated by reference to the classification of rocks which is based on their origin (genetic classification). The origin and conditions of rock formation predeter-

mine their chemical and mineralogical composition, crystalline structure and texture. According to the genetic classification, rocks are subdivided into three large groups: igneous, sedimentary and metamorphic.

Igneous rocks have been formed from fused magma ejected from the earth's interior and solidified by cooling. Diverse conditions of cooling have resulted in the formation of igneous rocks of various textures and properties. In some cases magma has not come out on the earth's surface, but has solidified underneath its upper layers, giving rise to deep-seated rocks. In other cases, magma has flown out and solidified on the surface of the earth to form effusive rocks.

Deep-seated rocks have originated under a considerable pressure exerted by the upper layers; they have cooled slowly and relatively uniformly. These conditions have favoured the crystallization of minerals making up the rocks. Owing to this, the deep-seated rocks are massive and solid and often consist of relatively large crystals tightly pressed together; they have high bulk density and heat conductivity, great compressive strength and frost resistance, and low water absorption.

Deep-seated rocks have a granular crystalline structure, sometimes referred to as granite structure.

Among the igneous rocks, distinction is made between the massive and the fragmental varieties, the latter resulting from the disintegration of massive rocks. The chief representatives of massive deep-seated rocks are granites, syenites, diorites and gabbro.

Granite is used for facing slabs, staircases, floors, curb stones, crushed stone, etc. Granite is also used in the construction of hydraulic engineering installations and for monuments.

Syenites, which are softer and more resilient than granite and show greater amenability to polishing, are used for the same purposes as granites.

Diorites are hard to work, and have good polishing qualities, high resistance to abrasion and to weathering. Diorites are used for road construction and as facing slabs.

Gabbro is resistant to weathering, is hard to work, but its polished surfaces are very durable. It is used for hydraulic engineering and other kinds of installations in the form of rubble, facing slabs, etc. Labradorite of beautiful colouring is used as a facing material.

Effusive solid rocks have been formed near or on the earth's surface in the absence of pressure by rapid cooling of the effusive magma which also carried crystals of various minerals. This is why the majority of effusive rocks consists of separate perfectly-formed crystals impregnated into the body of the cryptocrystalline mass; this structure is called porphyritic. When effusive rocks have cooled near

the earth's surface in a massive layer, their structure was similar to that of deep-seated rocks. When on the earth's surface, the layer was relatively thin, upper layers of the effusive lava became porous because of an intensive release of gases from the magma as pressure diminished. Referred to these rocks are pumice and volcanic ash, which have cemented to give volcanic tuffs. Therefore the structure of effusive rocks may be semicrystalline, glassy or granular.

Diabase, basalt, andesite have glassy structure.

Diabase is amenable to polishing; its colour is dark-grey. It is used in the form of crushed or piece stone, slabs, paving blocks, facing material. Various items may be cast from molten diabase at temperatures between 1200 and 1350°C. Cast diabase is resistant to acids and alkalis, has good dielectric properties and a compressive strength somewhere around 500 MPa.

High hardness and strength of basalts make them suitable for road pavings and also for the manufacture of cast stone mouldings.

Andesite being an acid-resistant material is used as aggregate in acid-resistant concretes and also for special facing jobs.

Pumice occurs in fragments 5 to 50 mm across, ejected during eruptions of volcanoes. Bulk density of lump pumice is 400 to 1400 kg/m³; porosity before 80%; compressive strength, 0,4 to 2,0 MPa. Pumice is used as aggregate for lightweight concretes, as heat insulating material and as an active mineral admixture (puzzolana admixtures) to lime and cements.

During volcanic eruptions, ashes and sands were mixed with molten lava to form tuff lava. Cemented tuff lava is called volcanic tuff. The bulk density of lump tuff is 1250 to 1350 kg/m³; porosity, 40 to 70%; compressive strength, 8 to 19 MPa. Its colour is rose-violet. Tuff is used as aggregate for lightweight concretes and mortars, for large wall slabs and as an active admixture to air-setting lime or cement. Excellent decorative qualities and frost resistance predetermine its wide use as a facing material for facades of buildings.

Sedimentary rocks have been formed by the precipitation of substances from solvents, mainly water. Precipitation occurred periodically and has resulted in separate layers and strata. By the character of formation and the composition, sedimentary rocks fall into three groups: chemical, organic and mechanical.

Chemical sedimentary rocks (e.g., gypsum, anhydrite) have formed by the precipitation of mineral substances from water solutions, the deposits then consolidating and cementing themselves.

Chemical deposits comprise gypsum, anhydrite, magnesite, dolomite and lime tufas.

Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) is used for the manufacture of an air-setting binder (building gypsum) and also as a facing material (artificial marble) for interiors of buildings.

Anhydrite (CaSO_4) is used for facing and as a source material for the manufacture of anhydrite cement.

Magnesite (MgCO_3) is also a raw material for the manufacture of air-setting binding materials (caustic magnesite) and refractories.

Dolomite ($\text{CaCO}_3 \cdot \text{MgCO}_3$) is the source material for crushed stone, facing slabs, refractories and binding materials (air-setting binder: lime and caustic dolomite).

Lime tufas are used as raw materials for the production of lime, whereas dense tufas with characteristic fine and uniformly distributed pores are employed as piece stones for walls and aggregate for lightweight concretes.

Organic rocks have been formed of remnants of seaweeds and living organisms consolidated and cemented together. Classed with the organogenous rocks are most of the limestones, chalk, diatomites.

Organogenous rocks comprise limestone, shell limestone, chalk, diatomites and tripoli.

Limestones are used for the manufacture of crushed stone, facing slabs and architectural items, and also for the production of lime and Portland cement.

Shell limestone is a porous rock composed of shells and their fragments cemented together by lime. It is used for the manufacture of wall stones and blocks (slabs), and also as aggregate for lightweight concretes.

Chalk is a highly dispersed material. Its colour is white and it is used as a white pigment and in the manufacture of putty, lime, white Portland cement and glass.

Diatomite is a poorly cemented very porous (60-70%) siliceous rock formed of shells of diatom algae. Tripoli is lightweight, clay-like rock. Its porosity equals 60 to 70%.

Diatomites and tripoli are used for the manufacture of heat insulation materials, lightweight brick, and also as an active mineral admixture in hydraulic-setting binding materials.

Mechanical sediments (fragmental rock) have resulted from the deposition or accumulation of loose products in the process of physical and chemical disintegration of rocks. Products of disintegration were transported by winds and particularly by water streams over vast distances and then settled, thus giving origin to clays, sands crushed stone and gravels from massive rocks. Part of these has been subsequently cemented by clay substances, ferrous compounds, carbonates or other carbonaceous cements to give cemented sedimentary rocks, conglomerates, breccias.

Clay results from weathering of eruptive feldspathic rocks. Weathering essentially involves mechanical and chemical disintegrations. Clay is an earthen mineral mass or fragmentary rock capable of mixing with water and forming a plastic viscous mass, which on drying retains the shape it was given and after burning acquires the strength of stone.

Sand is a loose mixture of grains of various rocks ranging in size from 0,14 to 5,0 mm. By their origin, sands fall into rock, river, sea, dune, etc., varieties.

Gravel is rounded off stones and natural rubble measuring from 5 to 70 mm. It is used as an aggregate for concrete.

Sandstones are rocks composed of grains of quartz cemented by claylike, siliceous or limestone substances. The strength of sandstones is governed by the kind of the binding substance, the size and the shape of cemented grains. These rocks are used as crushed stone for concrete, for facing bridge piers and building foundations, and for road surfaces because they are highly resistant to frost and abrasion.

Rocks consisting of cemented stone fragments are called breccia, and those of grains of gravel are called conglomerates. Conglomerates and breccias are used as crushed stone for concretes, as well as piece stones and facing slabs.

Metamorphic rocks have formed as a result of more or less complete modification of eruptive or sedimentary rocks under the influence of high temperature and pressure. Under these conditions minerals may have recrystallized without melting, the resultant rocks being, generally more compact than original sedimentary ones. Metamorphism has also affected the structure of the rocks. In dependence from direction of pressure under the earth they should have a monolithic structure (quartzite's marble) or a shaly structure (gneisses slate). They are used mainly as facing slabs, rubble, stone for foundations and walls of non-heated buildings, paving stones for sidewalls. Clay shales are composed of solid shaly clays. Their colour is dark grey, sometimes black. Clay shales split readily, are weather-resistant and durable, which makes them particularly suitable for use as roofing materials. Marble is a crystalline rock, formed of limestones or dolomites. Its crystals are bound together without the intermediary of a cementing agent. It can readily be sawn and polished and is applied for facing building interiors, as its poor chemical resistance against some gases and atmospheric moisture makes it unsuitable for external application. Quartzites are metamorphic varieties of siliceous sandstones with recrystallized quartz grains intergrown to such a degree that the cementing substance is indistinguishable. Quartzites are fireproof, weather and acid resistant. Applications of quartzites include facing of buildings, bridge piers and manufacture of refractory items.

3.1.2. Mining and Working of Natural stone Materials

Rocks suitable for the manufacture of stone materials are called useful minerals. Rocks accompanying the minerals and not used for the aforementioned purposes are referred to as waste rock. Operations involved in obtaining minerals are called mining. Voids formed in the process of mining are termed excavations, and the mined deposits, quarries. Natural stone materials are mined chiefly in quarries by the use of excavators, hydromechanization techniques, stone-cutting machines for sawing massive rock, blasting, etc. Contemporary methods involve extensive mechanization of all production processes.

The choice in the method of mining the natural stone materials depends on the type of rock, depth and conditions of occurrence, hardness, etc. Loose rock materials, as sand, gravel and clay, are mined in quarries with the use of various excavators and also by applying the hydromechanization technique. Hydromechanization consists essentially of washing the soil away by jets of high-pressure water ejected from a monitor nozzle. This is followed by the separation of the commercial product (sand or gravel) from the water-soil mixture (pulp).

Sand and gravel are classified at the quarries into two or more size fractions. Crushed stone is obtained by crushing rocks mined by blasting or any other technique. Rock is crushed, screened and concentrated at crushing-and-screening plants located near the quarries.

Processes which result in stones being given specified shape, dimensions, and facing constitute the working of stones. Stones are worked by mechanical means in specialized plants. By the methods of manufacture, items and materials from natural stone are divided into the following, kinds:

- sawn, obtained from massive rock by stone-cutting and stone-splitting machines (semi-product blocks, large stones);
- sawn, obtained from semi-product blocks by appropriate working (facing slabs, single-piece treads, window-sill boards, etc.);
- roughly split, manufactured by oriented splitting of block with no working whatsoever (bedded stone);
- fractured, produced by blasting rocks and separating finer sizes (quarrystone);
- crushed, produced by crushing and screening (crushed stone, artificial sand);
- ground, obtained by grinding rocks (ground mineral powder, stone powder).

By the character of worked surfaces, split stones are subdivided into the following types of finish: “rock”, ribbed, grooved and pointed, all discussed below.

When stones are worked by abrasives, the following kinds of finish are obtained: a polished finish; a smooth glossy finish; a velvety lusterless finish with apparent stone texture; a mirror-like finish with a smooth surface and mirror luster.

3.1.3. Materials and Manufactured Items of Natural Stone

Natural stone materials, possessing high resistance to atmospheric agents, high mechanical strength and pleasant colours are widely used in construction as slabs for walls and foundations of buildings and installations, as facing slabs and stones for exterior and interior walls of buildings and installations, for roads, sidewalks, piers, unloading walls and other structures, the material of which is the subject of particular mechanical strength, durability and decorative requirements.

Foundations, hydraulic engineering structures, bridges and walls of underground parts of buildings are erected from quarry, split and sawn stones from igneous sedimentary and metamorphic rocks. The coefficient of softening of stones used for, these purposes should not be less than 0,8 and the frost resistance, not less than F25, compressive strength not less than 15 MPa. Piece stones, sawn and split from limestones, dolomite, sandstones, and volcanic tuffs are used for above-ground walls (piers of bridges, embankment and side slope reinforcements, relieving walls). Faces of wall stones and large wall slabs should be adequately decorative.

Facing slabs and stones, parts of stairs and landings, parapets and guard rails are made of slabs sawn or split from natural stone (granite, basalt, marble, limestone, volcanic tuffs) and worked by mechanical means their front face. Pedestal slabs and stones for framing doorways, belts of cornices, corner and window-sill slabs fall into the category of profile wall facing elements.

The following materials and items from natural stones are used in road construction: curbstones, paving blocks, hewn stone or cobblestone, crushed stone, sand and mineral powder. Materials and items for road construction are obtained from igneous and sedimentary rocks.

Materials and items from natural stones intended for use in high-temperature or corrosive media should be manufactured from non-weathered rocks. Materials and items for high-temperature working conditions are made from chromite, basalt, diabase, andesite, quartzite. Elements of buildings and apparatus are protected against acids by facing slabs made of syenite, quartzite, andesite, basalt, diabase. Protection against alkalis is provided by the use of solid limestones, dolomites, magnesite. Materials intended for protection against corrosion should have resistance to acids and alkalis, not lower than 95%.

Cast stone materials also possess high strength, resistance to abrasion and attack by corrosive agents. Source materials for cast stone are rocks of magmatic origin, mainly basalt and diabase, which feature low viscosity in molten state. Basalts are more uniform in chemical composition, and the stones cast from them possess high chemical and abrasion resistance.

Source materials for the manufacture of light-coloured cast stones are quartz sand, dolomite. Source materials are charged into bath furnaces, in which materials is melted at a temperature of 1450°C. Finished melt trickles out of the bath into a forehearth, where it cools to 1250°C. Cooling of the melt prior casting affects the structure of the items favourably and reduces the number of shrinkage defects (cracks, cavities).

Internal stresses due to cooling are lessened by crystallizing and annealing the casting. The degree of crystallization of the melt varies with its properties and the dimensions of the items. The items are crystallized and annealed in special furnaces at temperatures between 800 and 900°C, after which the items are transferred to the annealing zone, and then to finished items storage. Cast stone slabs are successfully used instead of metal ones to pave floors in corrosive-media workshops and to line apparatus exposed to severe abrasive conditions.

Crushed stone is a mixture of jagged stone fragments, measuring from 5 to 70 mm and obtained by crushing various rock. The strength of crushed stone is described by the ultimate strength of the source rock. From the standpoint of its use, the quality of crushed stone is determined by the grain size, content of foreign and harmful impurities, grindability and frost resistance.

Gravel is a loose agglomeration of rock fragments more or less rounded and measuring from 5 to 70 mm across.

Sand is a loose mass of mineral and rock particles measuring 0,14 to 5 mm across. By mineralogical composition, sand is divided into quartz, feldspar and carbonaceous varieties and is used for preparing mortars and concretes, for making road beds and drainage constructions.

3.1.4. Protection of Natural Stone Materials against Disintegration

Stone materials may disintegrate when attacked by water acting as a solvent; water containing carbon dioxide, sulphurous and other acid compounds is particularly aggressive. Stone materials disintegrate readily when exposed to alternate action of water and frost. A rock composed of several minerals may decay on account of temperature variations because of a difference in linear expansion coefficients of the various minerals.

Rocks may also be attacked by organic acids. Dust particles of non-organic and organic origin (from domestic or industrial waste of cities) settle on the surface and penetrate into the pores of stones; their wetting with water initiates bacteriological processes, the resultant microorganism producing acids which attack the stones. The rate of decay of a rock is also governed by its quality and structure, or, more specifically, by the presence of microcracks, microstratifications and soakable and soluble substances.

To preserve stone materials against decay, it is imperative first of all to prevent the penetration of water and solutions deep into the materials by a technique known as fluating (fluosilicate coating). Treatment of limestone by fluates (for example, magnesium fluosilicate) produces salts in the stones and thus enhances its impermeability to water and resistance to weathering.

Facing stones are protected against the action of carbon dioxide and the formation of sulphates by impregnating them to a depth of 1 cm by hot linseed oil. Stones are made waterproof by a coating of a turpentine solution of wax, of paraffin dissolved in light oil distillate, or of cool tar. Stone materials may be protected also by providing efficient water drainage from their surfaces, by a very smooth finish of their surfaces.

3.2. Ceramic Materials and Items

Ceramic materials are manufactured from clay compositions by moulding and subsequent burning, an intermediate drying of freshly moulded items being a frequent practice.

Universality of properties, a wide range of products, high strength, durability and reasonable cost of ceramic items underlie their wide use in the most various subassemblies of buildings and installations, such as walls, heating units, wall and floor facing materials, sewer pipes, lining materials for chemical industry apparatus and light porous aggregates for prefabricated reinforced concrete items (pic. 13-17).

3.2.1. Raw Materials and Properties of Clays

Clay results from weathering of eruptive feldspathic rocks. Weathering essentially involves mechanical and chemical disintegrations. Clay rocks capable of mixing with water and forming a plastic viscous mass, which on drying retains the shape it was given and after burning acquires the strength and water resistance of stone. Workability of clays is improved and the manufactured items are given required physical and chemical properties by blending clays with quartz sand, chamotte (refractory clay burned at 1000-1400°C and crushed), slag, sawdust, pulverized coal.

Properties of clays are characterized by plasticity, cohesion and cohesiveness and their response to drying and high temperature.

Plasticity is an essential working property of clays which allows moulding various ceramic materials and items. The degree of plasticity of clay depends on its mineralogical and granulometric composition, on the shape and character of grain surface, on the content of soluble salts and organic impurities and on the amount of water used for preparing the clay mass. The high plasticity clays let to shrinkage during drying (air shrinkage) and burning (fire shrinkage) of items therefore in these clays the addition of the leaner (non-plastic) substances (sand, slag, fireclay).

Cohesion and cohesiveness. Clays with high content of clayey fractions feature high cohesion. Cohesiveness of clays drops with an increase in content of sand and dust fractions. This property of clays is of great importance in the moulding process. Cohesiveness of clay is characterized by its ability to bind together particles of non-plastic materials (sand, chamotte and others) and to form on drying a sufficiently strong item of desired shape.

Effect of high temperature on clays. The important property of clays is their ability to turn to a stone is the process of burning. Mechanically mixed water is eliminated at the initial temperature increase; the organic impurities burn out when the temperature ranges from 550 to 800°C with the effect that clay loses its plasticity. Burning is a process which takes place when the temperature is raised above the 800°C mark; in the process, the easy-fusing clay components melt, spread out and envelop particles that are still solid; when cooled, the molten mass solidifies and cements the particles. Burring of clay transforms it into stone. The colour of burned clays is affected mainly by the content of iron oxides which give the ceramic items a red colour.

3.2.2. General Production Flowsheet for Receiving Ceramic Items

Despite the wide range of ceramic items, the great variety of their shapes and of the physical and mechanical properties of raw materials, the basic production steps are common to all the items and involve the following operations: mining of raw materials, preparation of raw paste; molding of items; drying; burning of items; finishing of items (trimming, glazing, etc.) and packing.

Raw materials are quarried by the open pit method with the aid of power shovels. Preparation of raw materials involves disintegration of clay's natural structure, removal or grinding of large inclusions, mixing the clay with admixtures and water until a readily mouldable mass is obtained.

Depending on the properties of raw materials and on the kind of items produced, ceramic mass is prepared by the stiff-mud, soft-mud and slip casting methods.

In the stiff-mud method, clay is first crushed and dried, then ground and molded at a moisture content, from 8 to 12%. In the stiff-mud method, the clay is moulded in hydraulic or mechanical presses at pressures of 15 MPa and over. The soft-mud moulding method involves crushing of clay, then processing it in a mixer, where it is mixed with lean admixtures and simultaneously humidified until a homogeneous plastic mass of moisture content from 20 to 25% is obtained. In the soft-mud method, ceramic items (brick for wall, pipes, and tills for facing walls) are manufactured mainly in auger machines.

In the slip casting method, the starting materials are ground and mixed with a large amount of water (up to 60%) until a homogeneous paste (slip) is obtained. The mass is directly cast into moulds. Using this method, small-size ceramic tiles for façade decoration and sanitary ceramic items are manufactured.

3.2.3. Ceramic Materials and Items

Ceramic items used in the building industry are classed according to their applications: wall materials, brick and clay building stones for special purposes, ceramic items for floors, ceramic items for façade and interior decoration, roof materials, sewer and drainage ceramic pipes, acid-resistant lining items, sanitary ceramic items, ceramsite gravel, refractory materials.

Wall ceramic materials

Wall materials are common clay brick, perforated clay brick, porous and perforated stiff-mud brick, hollow clay dry-press brick, perforated plastic, moulded ceramic stones and light weight building brick.

Clay brick, both solid and hollow, of either soft-mud or stiff-mud moulding, is an artificial stone manufactured from clay with additives (sand, slag, sawdust and others) and burned. Brick should be shaped as a parallelepiped with straight edges, right angles and smooth faces. Brick is available in ordinary size 250×120×65 mm and module size 250×120×88 mm, 288×138×65 mm, and 250×54×88 mm. The module brick with moulded voids is not more than 4,3 kg in mass. There are eight grades of brick designated 75, 100, 125, 150, 175, 200, 250 and 300 (7,5-30 MPa), which indicate respective compressive strengths. Bricks of each grade should also meet specific requirements as regards their bending strength from 2 to 4,4 MPa respectively. It is necessary that normally burnt bricks should have a water absorption of not less than 8% of the weight of a brick dried to constant mass. By their frost resistance, bricks are subdivided into six grades: F15, F25, F35, F50, F75 and F100; bulk densities from 1450 to 1600 kg/ m³.

Common clay brick is used for building brick panels of exterior and interior walls, for brickwork of outside and inside walls, pillars, foundations, and

other bearing construction. Clay brick manufactured by the stiff-mud moulding method should not be used for foundations and pedestals below the damp course because of poor frost resistance.

Hollow clay brick is manufactured by the soft-mud and the stiff-mud moulding methods with special devices (punches) for making holes (voids) in the brick. Voids should be located at right angle to the bed. In shape, they may be round (diameter not more than 15 mm) and rectangular (slot width not more than 15 mm). Hollow brick is manufactured in sizes of 250×120×65 mm, 250×120×88 mm, 288×138×65 mm and 250×120×138 mm, in compressive strength grades of 25, 35, 50, 75, 100 and 125; bulk densities from 950 to 1400 kg/m³; water absorption, not less than 6%, and frost resistance, not less than F50. Hollow clay brick is used for outside and inside bearing walls, partitions and other parts of buildings and installations. This brick should not be used for foundations, pedestal and walls of moist premises.

Lightweight building brick is a burned artificial stone from diatomites or tripoli with admixtures of clay or a combination of clay and burning-out admixtures (sawdust). As compared to common brick, lightweight brick has a lower bulk density and heat conductivity. Its use allows to reduce wall thickness and weight of constructions and to increase floorspace of buildings. This brick is manufactured in sizes of 250×120×65 mm, 250×120×88 mm with a bulk density from 950 to 1400 kg/m³, and has a compressive strength of 7,5-12,5 MPa. Its frost resistance should not be less than F50.

Ceramic stones have smooth or riffled surfaces and through or closed voids. Dimension of stones are as follows: length, 250 to 510 mm; width, 120 to 250 mm; thickness, 138 to 219 mm; bulk density, 790 to 1300 kg/m³; water absorption, not less than 11%, and frost resistance, not below F75. Ceramic stones have a compressive strength from 10 to 25 MPa.

Ceramic items for building facades and interior facing

Building facades are faced with various ceramic materials such as facing bricks and stones, paper-mounted ceramic tiles. Which differ not only in shape and dimensions, but also by the ornamental effect they produce. These items should have not only low weight, high strength and frost resistance, but also beautiful natural colour.

Facing bricks and stones are not only decorative items; they are laid together with the wall brickwork and also serve as structural bearing members, along with common brick. Facing brick and stones are available in solid and hollow types. The surface of facing bricks is coloured by specially developed variously coloured frost resistant engobe or glaze compositions (white, green, sky

blue, etc.). The face of brick and stone may be smooth, riffled or textured. Facing brick and stone are available in grades 75, 100, 125 and 150, with water absorption from 6% to 14%, frost resistance should withstand not less than F25. Hollow and solid facing brick and stone are used for exterior brickwork of building facades and for interior walls laid simultaneously with the exterior walls, and for internal finishing of ware-houses, plant shops and protective enclosures in gardens and parks. Only glazed brick or one with water absorption of not more than 5% should be used for water pools and reservoirs and other similar installations.

Paper-mounted glazed and unglazed ceramic tiles are small-size, thin, variously coloured tiles glued upon a paper sheet to form a mosaic. Mosaic facing tiles are generally manufactured by casting. Tiles may be manufactured in various colours, shiny and lusterless, coated with translucent or opaque glazes; they are manufactured in a range of 32 types and sizes, in square, rectangular, triangular, rhombic and trapezoidal shapes with sides measuring from 25 to 125 mm. Paper-mounted ceramic tiles should satisfy the following requirements: water absorption, not less than 6% and not more than 12%; frost resistance, F25.

Ceramic tile facing of bathrooms, bath houses, laundries, hospitals and other premises has now become a standard building practice, two types of tiles – wall and floor varieties being used for the purpose. Wall tiles are divided into majolica and faience kinds, according to the raw materials used. Majolica tiles are manufactured from low-heat clays to which up to 20% calcium carbonate is added in the form of chalk. Burning produces a porous tile shell, its face side is glazed, and the back side is fluted to improve adhesion to the wall surface. Faience tiles are made from refractory, clays with additions of quartz sand and fusing agents (as a rule, fluorspar and limestone or chalk) which lower their melting point. The tiles have a white or a slightly coloured shell, whose face side is coated with white or coloured, translucent or dead glaze. Their back side is generally riffled. Tiles are available in a square, rectangular and other shapes intended for angles, cornices and plinths. Tiles for interior facing are manufactured in the following sizes: length, 150 mm, width, 25, 50, 75 and 150 mm. Thickness of tiles of all sizes should be from 6 mm to 12 mm. The quality of tiles intended for interior facing must be very high. The tiles should be of regular geometric shape, free of bulges, hollows or cracks.; they should be sufficiently heat resistant, i.e., withstand alternate cycles of heating to 100°C and cooling in water at 20°C without any cracks, chips or crackles appearing on the glazed surface. Water absorption of tiles should not exceed 16%. Wall tiles are used to face walls of premises requiring extra cleanliness, sanitary closets, kitchens and premises of high moisture content.

Ceramic floor tiles are extensively used in dwelling. They are durable and impervious to water resist abrasion well and wash readily. On the other hand, ceramic materials have a number of shortcomings: high heat conductivity, low impact strength and small dimensions. The two methods of preparing masses for moulding generally used in the manufacture of tiles are the soft-mud and the stiff-mud methods. Altogether tiles are manufactured with sides measuring from 50 to 150 mm and in thicknesses from 10 to 13 mm. Tiles should be of regular shapes, have sharp edges and angles and be free from bulges, hollows and cracks; they should be very dense, and their water absorption should not exceed 4%; their resistance to abrasion should be high (loss in mass of tiles tested for abrasion should not exceed 0,1 g/cm² for floors subjected to severe abrasion and 0,25 g/cm² for floors of other premises. Ceramic floors are intended for premises with intensive pedestrian traffic and moisture, such as sanitary and service, premises, lobbies, halls, entrances to public, industrial, buildings and underground railway stations.

Ceramic materials for special application

Ceramic material for special purposes are curved clay brick, stones for sewage installations and brick clinker) for road surfaces. The above materials have to meet stringent requirements as regards mechanical strength, resistance to frost, abrasion and impact.

Curved clay brick is used for brickwork of industrial chimneys and for lining pipes, when they are heated by flue gases to a temperature not higher than 700°C.

Brick (clinker) for road surfaces is an artificial stone moulded from clay and subsequently burned until cured, but not glazed. The raw materials used are high-heat clays. Clinker is manufactured in a single size of 220×110×65 mm.

Stones for sewage installations should have high density. They are trapezoidal in shape and are used for lining pits of 1,5 and 2 m in diameter. Stones for each diameter are available in two types and can be assembled into rings with the aid of side grooves and tongues. Ceramic stones for underground conduits should have a compressive strength of not less than 20 MPa.

Clay roof tiles are relatively cheap and possess good ornamental properties. Their drawback is a considerable weight (up to 65 kg per 1m² roof). Extensively used in construction practice are roof tiles of four types: stamped, valley, flat ribbon and ridge tiles. Roof tiles should be well burned, uniformly coloured, have an even and smooth surface (no cracks), be sufficiently strong (breaking load not less than 70 kgf), impervious to water and frost resistant (not less than F25).

Ceramic sewer pipes are used for industrial and fecal sewer systems, and for draining systems for corrosive water. Sewer pipes are available in diameters

from 150 to 600 mm, and in lengths from 800 to 1200 mm. Water absorption of the pipe should be from 9% to 11% (by weight). The pipes are rated to withstand hydraulic pressures not less than 0,2 MPa and the shell's resistance to acids should not be less than 90%. Draining pipes are manufactured in diameters from 25 to 250 mm, in lengths of 333-500 mm. They should be sufficiently frost resistant (F not less than 15).

Acid-resistant brick is used for foundations and linings of chemical apparatus, floors and discharge troughs at chemical plants. Acid-resistant brick is manufactured in two kinds: straight and wedge. Acid-resistant brick should have acid resistant not less than 92-96%, water absorption, not more than 8-12%, compressive strength, not less than 15-25 MPa, heat resistance (number of thermal cycles), not less than 2. Acid-resistant ceramic tiles are available in two types: acid-resistant (K), thermal-and-acid resistant (TK). Tiles have a solid burnt body, high strength (compressive strength not less than 39 MPa and bending strength not less than 15 MPa), low water absorption (not more than 6 to 9%), high acid resistance (not less than 96-98%), and a high heat resistance (not less than 2 and 8 thermal cycles). These tiles are used for lining chemical apparatus and floors at chemical plants. Acid-resistant ceramic pipes have a solid burnt body, glazed on both sides. Acid-resistant pipes are distinguished by high density and strength, low water absorption and high resistance to acids. Acid-resistant pipes are used for handling non-organic and organic acids and gases in vacuum or at pressures up to 0,3 MPa.

Sanitary ware items are manufactured mainly from white-burning refractory clays, kaolins, quartz and feldspar. There are three groups of sanitary ceramics: faience, semi-porcelain and porcelain, which differ in degree of caking and as a consequence, in porosity. Items from faience have a porous shell, and items from porcelain, a solid shell, while those from semi-porcelain are of intermediate densities. The various degrees of caking of faience, porcelain and semi-porcelain, made of the same raw materials, are due to the latter's different proportion in the working mass. Solid faience is used mainly to manufacture toilet bowls, wash basins, toilet tanks and bath tubs. Items are glazed, since unglazed faience is water permeable. Porcelain outer shell is impervious to water and gases and possesses high mechanical strength and resistance to heat and chemical agents. Porcelain is used to manufacture insulators, for power transmission lines, chemical laboratory vessels, etc.

Materials of a refractoriness above 1580°C are called refractories; generally, they have to meet certain specifications as regards refractoriness, compressive and bending strengths, resistance to loads at high temperatures, spalling re-

sistance, gas impermeability, resistance to slag, constancy of volume and shape. Of the refractory materials, most widely used are the siliceous (silica) 1670-1790°C, chamotte 1670-1790°C, high-alumina 1820-1960°C. Refractory materials are used for roofs in metallurgical, ceramics furnaces and glass tanks.

Ceramsite is a lightweight porous material of cellular structure with closed pores. It is used mainly as aggregate for lightweight concretes and as heat-insulating material. Ceramsite is manufactured from low-heat clays. The clay is crushed, dried, ground, thoroughly mixed with organic additives (pulverized coal, peat crumbs) and finally pelletized to produce balls 10 to 20 mm in diameter. In the process of burning, the materials soften, and the evolving gases and water vapours cause the semi-liquid mass to expand and form pores. Ceramsite gravel is classified by size of pellets, bulk density and mechanical strength. It is available in pellets from 2, 5 to 20 mm in diameter, grains smaller than 5 mm being called ceramsite sand. By its bulk density, gravel is divided into grades from 200 to 900 (kg/m³), with compressive strengths from 0,5 to 10,0 (in MPa).

3.3. Materials from Mineral Melts

Mineral melts may be divided according to their source material into glasses, slags and stones. These materials possess good physical and mechanical properties (are resistant to acids and abrasion, impervious to water, and decorative).

Materials and items from glass melts, such as various glasses and finished items, have found extensive application in construction, architecture, sanitary engineering, food, chemical and other industries (pic. 18-20).

Glass has a number of properties, which other constructional materials lack, the most characteristic of which are transparency to light and brittleness. The compressive strength of glass may be as high as 700 to 1000 MPa, the tensile strength, 30 to 80 MPa. Common silicate glass is transparent to the entire visible part of the spectrum and practically opaque to ultraviolet and infra-red. Transparency of glass within the above range of wavelengths may be controlled through its chemical composition and colour. Silicate glass is highly resistant to attack by various agents, except hydrofluoric and phosphoric acids.

Variety and application of sheet glass

Window sheet glass is a widely used kind of flat glass; it is available in thicknesses from 2 to 6 mm. The light transparency of window glass ranges from 85 to 90%, depending on its thickness.

The source materials for the manufacture of structural sheet glass are quartz sands, sodium sulphate or soda ash, limestone, dolomite and a number of other substances. The manufacture of structural glass consists of the following

main operations. The preparation of constituent materials involves drying, crushing, proportioning and mixing the ingredients. Once a charge is prepared, it is melted in special furnaces, at 1100-1200°C. Next, the melt is taken up by a vertical or horizontal type drawing machine and shaped into a sheet by passing between rolls, then cooled using a special regime to reduce brittleness. Sheet glass may also be manufactured by casting and subsequent rolling. For this purpose, a glass melt is poured on a smooth surface of melt and rolled between smooth or figured rolls.

Window sheet glass is available in the following varieties:

1. Decorative glass; one side has a smooth, and the other, a relief figured surface.

2. Wire glass obtained by continuous rolling with simultaneous imbedding inside of a wire mesh. Wire glass may be smooth, moulded or variously figured and colourless or coloured. This glass is used for guarding balconies, loggias, stairs, elevator pits, for decorative translucent domes and partitions in dwelling houses, sanatoriums, rest homes, and public catering.

3. Safety glass is obtained in vertical drawing machines through a special processing of the glass by special compounds. The chemical composition of the compounds and the processing conditions may be so adjusted as to produce glass with different light and heat transmission and reflection characteristics for various spectrum ranges. Safety glass is used for glazing buildings.

4. Heat-absorbing glass, coloured throughout its body, contains special additives, which selectively absorb infra-red rays of the solar spectrum. It is intended to reduce insolation. The transmission of visible light amounts to no less than 65%, and that of infra-red rays, to not more than 35%.

5. Shopwindows glass is manufactured from polished and unpolished glass, 6 to 12 mm thick, in panels of 4 to 12 m². It may be either flat or curved. Shop window glass is used for glazing inside and outside shopwindows and openings in shops, restaurants, airports. Sheet glass is used for glass slabs and door panels.

6. Glass slabs are two or a number of glass sheets fused together hermetically along the perimeter. The cavities between the glass sheets contain dry air. Glass slabs are manufactured from window, show window, armoured, art, etc., glass, 2 to 8 mm thick, of surface areas up to 5,0 m², the panes being spaced 15 to 20 mm apart. Glass slabs are capable of withstanding greater wind loads than separate glass sheets of the same thickness. Glass slabs are also good sound insulators. They are used for glazing industrial, civil and public buildings.

7. Door panels are made from special heat-cured (tempered) glass sheets with thickness from 10 to 15 mm. The available range of door glass panels is as follows: colourless, transparent, with polished or unpolished surfaces; coloured

and colourless light diffusing with art or worked faces. Colourless glass panels are used for outside and inside doors in residential, public and industrial buildings. Coloured and colourless panels from rolled art or figured glass are used in inside premises where no through visibility is desired.

Constructions and items from glass

Profile structural glass is channel and boxed elements, which may be colourless or stained, in length of up to 6000 mm and in width from 244 to 294 mm. The manufacture of profile glass of channel cross section reinforced with a steel wire mesh is being introduced industrially at the present time. It is highly fire-resistant and splinter-proof.

Constructions from glass parts should be interlayered with various sealing devices, such as putties or specially designed profiled parts from foam rubber or synthetic materials.

Profile glass is used for translucent partitions and self-supporting walls in industrial, civil and agricultural construction work and for interior partitions and transparent flat roofs in various types of buildings. Profile glass may also be used in the form of large-size panels. This glass resists attack by concentrated acids, alkalis and humidity. Profile glass may be used in combination with metal, concrete, brick or wooden construction elements.

Glass blocks are hollow translucent items with variously figured inside and outside surfaces. Glass blocks are obtained by fusing two preheated half-blocks together. The air enclosed inside the slab (at a low vacuum) brings down the heat conductivity coefficient of the blocks. Glass blocks produce a soft diffuse lighting, enhance the depth of natural lighting, eliminate through visibility. Enclosing structures built of glass blocks present excellent fire-resisting and sound absorption properties. Glass blocks feature also high sound insulation properties. They are durable and hygienic. Glass blocks are used for fronts of industrial buildings, and for day-light illumination of stairways of civil buildings and various storage premises; glass blocks are also used for ornamental purposes, and find successful application in shops with aggressive atmosphere which require illumination. Glass blocks are also used wherever the character of the production process calls for invariable climatic conditions.

Glass-concrete structures, depending on their supporting power, opaqueness, sound insulation and other properties, are subdivided into wall, floor, roof and dome constructions in which the bearing part is a reinforced concrete carcass filled with glass blocks. Glass-concrete wall structures may be successfully used for industrial and service premises, railway stations, and exhibition pavilions. Wall structures (panels) possess adequate heat and sound-insulating properties, provide good lighting of premises, are hygienic and require no special finishing.

Facing items from mineral melts

Facing glass is used in the following varieties: sheet glass, coated on one side with solid ceramic paints of various colours (stemalite) or by applying a metallic oxide in not transparent glass melt (marblite) and carpet-type art glass tiles. Sheet glass has 6 to 12 mm thick, of surface areas up to 3.0 m². Tiles, available in sizes of 18×18×4, 20×22×4 and 23×23×3 mm, are durable and colour-fast. These tiles are intended for outside and inside facing for wall of buildings.

Sitals and slagsitals are vitrified crystalline materials. Molten slag or glass is blended with admixtures to improve its composition and with modifiers (generally, TiO₂, CaF₂ and P₂O₅) to accelerate the crystallization of molten. As the modifiers are but partly soluble in the body of mineral molten, they serve as crystallization nuclei. Next step is the moulding of items from the improved and modified molten. The major problem in the moulding of items is to choose correct conditions of thermal processing.

A material of required mechanical and thermal properties may be obtained by controlling the degree of crystallization and the composition of the crystalline phase. As compared to the manufacture of these items, that of sitals and slagsital requires thermal curing to transform glass to a vitrified crystalline state. Sitals may be dark, brown, grey, creamy light in colour and either dead (opaque) or transparent. Sitals and slagsital items possess excellent physical and engineering properties, high resistance to abrasion and attack by chemical or atmospheric agents and are non-toxic. They may compete with basalts and granites in durability. The combination of physical and mechanical properties of sitals and slagsitals predetermines their wide use in building practice: they are used for floors, of industrial and civil buildings, decorative and protective facing of exterior and interior walls, partitions, socles, lining of structural elements subject to corrosive or abrasive conditions, roof coverings of heated and non-heated industrial buildings, facings of laminated panel walls of multi-storey, buildings.

Items of special use from mineral melts

Glass pipes are available, in diameters from 15 to 65 mm. These items have found extensive application in the food, pharmaceutical, chemical and other industries for handling corrosive liquids. Glass pipelines are transparent, hygienic and smooth, a factor minimizing resistance to the flow of liquid.

Glass (slag) wool is a material composed of thin 5 to 6 mm flexible threads. Glass wool has high tensile strength and chemical resistance, low sound- and heat-conductivities and is obtained by mechanical drawing and centrifugal or blowing techniques.

In the centrifugal method, the source materials are furnace slags or glass bottle waste, which are washed and charged into a special ladle, where it melts,

and at 1300 to 1400°C flows into a pot. Next, the glass mass is blown in a thin jet onto a rapidly rotating disk. The centrifugal force causes the molten mass to break away from the disk and stretch into thin threads.

In the blowing technique, the threads are formed by breaking up the molten glass (slag) by a gas jet. A high-speed gas jet draws the glass mass into thin threads, which are then taken up by a fine wire conveyor and transferred to subsequent processing stages.

The manufacture of items (mats, slabs) from mineral fibre consists of the following operations: mixing of fibres with synthetic binders, moulding, thermal processing cutting and packing. The mats and rigid slabs are good heat-insulating and acoustic materials and have been finding in recent years an ever growing application in building practice.

Items from mineral fibre are used for heat insulation of building structures (walls, floors, roofs), refrigerators and pipes at temperatures between -60 and +180°C.

Acoustic materials by application are subdivided into two main groups: soundproofing and sound-absorbing ones.

Soundproofing materials and items are used chiefly in the form of liners and interlayers in floors, interior and exterior walls and other parts of buildings in order to damp impact noises transmitted through floors (walking), vibration (machine operation), etc. These materials are of a porous-fibrous structure (based on slag or glass wool), which are shaped as slabs, rolls, mats, strips and piece liners. By the relative compression under load, a distinction is made between rigid, semi-rigid and soft sound-insulation materials. Glass and mineral wool mats and slabs on synthetic binder have a bulk density of 50-225 g/m³, a relative compression factor of 15-40% under a load of 0,02 MPa, and a dynamic modulus of elasticity of 0,3-0,7 MPa.

Sound-absorbing materials lower audible noise (a combination of numerous sounds which rapidly vary in frequency and amplitude) in industrial and public buildings. Sound-absorbing materials on the base of mineral fibre have a porous-fibrous structure. They are divided into soft, semi-rigid and rigid varieties. Sound-absorbing materials are available as boards, coiled and loose materials; they are also used in the form of plaster boards having a smooth-porous, perforated and grooved structure.

Mineral wool acoustic (soundproofing) boards are manufactured from mineral fibres by impregnating them with a synthetic binder or granulated mineral wool and compositions of a starch binder with additions and subsequently submitting them to thermal and moisture curing in special chambers. The face of boards may also have directional cracks similar to the texture of weathered lime-

stone. Excellent ornamental properties of the mineral wool acoustic boards underlie their wide use for facing ceilings, entrance halls, theaters, concert halls, radio studios and noisy premises.

Cellular glass is obtained by causing molten glass to expand when mixed with a substance (limestone, coal) capable of giving off gas at temperatures of 750 to 850°C. This glass is a good heat-insulating and acoustic material, and has a small bulk density (140-350 kg/m³) and a low coefficient of heat conductivity (0,06 to 0,11 W/m °K). Cellular glass finds practical use as heat-insulating material (slab, bloc) in floors, walls as sound-absorbing material in public and service premises.

Thermosite (slag pumice) is a cellular material obtained by expanding molten slag as it is being rapidly cooled. The bulk density of thermosite ranges from 300 to 1100 kg/m³ depending on the size of lumps and the degree of expansion. Expanded thermosite is a good aggregate for the manufacture of light-weight concrete. Items of various profiles and configurations may be obtained by casting molten slag into special moulds.

Internal stresses may be lessened and cracks prevented during crystallization and subsequent cooling by placing a steel reinforcement into the moulds before slag is poured.

3.4. Metals and Metal Items

Metals and metallic alloys are crystalline bodies, composed of a host of separate grains consisting of crystalline formations bound together strongly. Iron may exist in several crystalline forms differing in arrangement of atoms.

In the process of solidification of a melt, first formed are regularly shaped fine crystals, and, as the metallic body cools, they increase in size and grow together into deformed irregularly shaped crystals (crystallites) which are readily visible through a microscope.

This phenomenon is known as allotropism. Allotropic changes are due to variations in temperature.

Allotropy is of great significance in hot working and heat treatment of cast iron and steel and adjustment of their amounts through hardening, annealing and other techniques provides required mechanical properties of steels.

Metal items are used for production of bearing structures, roofing and finishing materials (pic. 21-23).

3.4.1. Chief Properties of Metals

Physical properties of metals and alloys are described by their colour, density, melting point, heat conductivity and coefficient of thermal expansion.

Density of most metals is higher than 7000 kg/m^3 , but that of light metals (aluminium) is less than 3000 kg/m^3 . The lower is the density, the lighter and more efficient are the metal structures made of it. This explains why constructions from aluminium-based alloys are being used on ever increasing scale in building practice.

Melting points of metals are major factors in the choice of their hot working and casting procedures. The melting point can be changed by adding other substances. The variation of the melting temperature of a metal depends on the content of other substances and is described by the phase diagram.

Thermal expansion of metals is expressed by coefficients of linear and volumetric expansions. This property of metals should be taken into account when designing metal structures, because excessive expansion or contraction may cause their failure. It is very important to consider this phenomenon in the process of welding since the items being welded together may crack as a result of local heating. Thermal expansion of metals is taken into account in the manufacture of reinforced concrete items in which the reinforcement is tensioned by electric heating.

Mechanical properties of metals are their strength, hardness, resilience (impact strength), fatigue and creep. Strength is the ability of metal or alloy to withstand the action of external forces. Depending on the nature of these forces, distinction is made between tensile, compressive, bending and torsional strengths, these being presented by corresponding ultimate strengths, i.e., stresses which cause the tested specimen to fail. The tensile test is a universal test for all metals and alloys. Specific, say, for grey iron, are the compressive and bending tests. When testing metals for tensile strength, distinction is made between the ultimate strength (breaking point) and the yield point, or a stress when specimen elongates while the load remains constant. This characteristic is a basic factor in the calculation of metal constructions.

Specimens of steels and non-ferrous heavy and light alloys used for making parts working under repeated alternate tensile, bending, compressive, torsional, impact and other kinds of stresses, are tested for fatigue, or endurance.

Metals operating under continuous stresses are tested for creep, i.e., deformation under a constant load. Creep may cause excessive sag in constructions and loss of stability. Creep in the reinforcement of prestressed concrete constructions is particularly hazardous, since it may lead to the loss of pre-tension by the reinforcement, formation of cracks in concrete and failure of the entire construction.

Hardness of metal is defined by its resistance to the penetration of a hard steel ball (Brinell hardness), or a diamond cone or a pyramid.

Viscosity is generally considered in static and impact (dynamic) aspects. Static viscosity is expressed in terms of relative elongation, and impact viscosity, by the amount of work required to cause failure of an impact test specimen.

Workability of metal is its amenability to various mechanical processing. The term workability includes plasticity (which allows to produce metal items by forging, rolling and drawing), machinability and weldability (which is the ability of metal to give strong joints when heated locally to a plastic or liquid state).

Interaction of metal with the surrounding medium may result in its disintegration, or corrosion. Distinction is made between chemical and electrochemical corrosion. Chemical corrosion arises whenever metal is attacked by dry gases and solutions of oils, gasoline, kerosene, etc. An example of chemical corrosion of metal is its oxidation at high temperatures, as a result of which its surface becomes covered with scale. Electrochemical corrosion arises when metal is attacked by acids and alkalis. The metal gives off its ions to the electrolyte and disintegrates in the process. The degree of corrosion will depend on the temperature, kind and concentration of the electrolyte. Acids and alkalis attack steel because they are capable of dissolving the resultant compounds.

Carbon dioxide or sulphurous gas of the air enhance corrosion, since metal attacking acids are formed when the surface of metal is humidified.

Corrosion may be local in character, when only separate areas are affected; it may be uniform, when metal is attacked evenly over its entire surface; it may be intercrystalline when only the boundaries of grains disintegrate.

There is a number of means to protect metals against corrosion, the simplest of which is to coat them with paints, varnishes, enamels. The resultant film isolates the metal from the action of the surrounding media (gases, moisture). There are also more efficient means of corrosion protection:

- alloying, or introducing substances which enhance corrosion resistance of the metal;
- coating with a film of a different metal, which is less susceptible of corrosion under given conditions (zinc, tin); e.g., surfacing a part with metal from an electrolyte (galvanic plating), spraying or dipping in a bath containing some other molten metal.

3.4.2. Classification of Metals

Metals for construction work may be broadly classified as ferrous and non-ferrous.

Ferrous metals are alloys of iron and carbon. Besides carbon, ferrous metals may carry small amounts of silicon, manganese, sulphur and other chemical elements. Ferrous metals are given specific properties by adding to them the so-called alloying substances, such as copper, chromium and others. By their carbon content, ferrous metals are divided into cast irons and steels.

Production of cast iron is the first step of metallurgical processes in the manufacture of ferrous metals from natural iron ores, which are a mixture of iron oxides and minerals called gangue and composed chiefly of silica, alumina, limestone and other compounds.

The products of the blast-furnace process are cast iron, blast-furnace slag, glue gas and dust.

Cast iron is alloy of iron and 2 to 4,3% of carbon. In special kinds of cast irons (e.g. ferroalloys) the amount of carbon may be as high as 5% or more. Silicon, manganese, phosphorus and sulphur greatly affect the properties of cast irons; sulphur and phosphorus embrittle them, whereas admixtures of chromium, nickel, magnesium, aluminium and silicon enhance their heat, wear and corrosion resistances. When these elements are added, cast irons are called alloyed. Depending on the form of carbon in cast irons, the latter are subdivided into grey (foundry) and white varieties. Conversion iron accounts for about 80% of the output. Conversion iron is generally processed to steel. Cast iron of grades C4 is grey iron, and MC4 is modified (high-strength) grey iron. Mechanical properties of cast irons are as follows: grade C4: 120-280 to 280-480; MC4: 280-480 to 380-600 (the first two figures indicate the tensile strength in MPa, and the two latter figures, the bending strength in MPa). Grey iron is the one mostly used for building purposes. In load-bearing constructions, cast iron is used chiefly in compression members (footings, columns); cast iron is also widely employed for manufacturing sanitary engineering fixtures (heating radiators, pipes), architectural and ornamental items. A considerable amount of cast iron goes for the manufacture of tubings for underground railway tunnels.

Steel is obtained from conversion iron by bringing down the content of carbon and other impurities. Modern techniques for manufacturing steel are the oxygen-converter, the open hearth and the electric steelmaking processes. Irrespective of the methods, the steelmaking process consists in the oxidation of undesirable impurities which either turn into slag or burn. Steel contains carbon in amounts of up to 2%. In contrast to the brittle cast iron, steel is plastic, elastic and mechanically very workable. By application, steels fall into structural (0,02 to 0,85% carbon) and tool (0,65 to 1,4%) varieties. Structural steels used in construction engineering, reinforced concrete and machine industry are very plastic and negligibly brittle. Greater amount of carbon makes tool steels very hard but increases their brittleness.

By chemical composition, steels are divided into carbon and alloyed varieties. In their turn, carbon steels are available in the following grades: common; high-quality structural (for general machine building and critical struc-

tures); and tool (for the manufacture of cutting tools and dies). Common grade carbon steel finds its basic application in construction work. Steel is an alloy of iron and carbon. It contains, besides carbon (0,06-0,62%), some silicon and manganese. Most undesirable is phosphorus, which causes brittleness at low temperatures (cold brittleness), and sulphur, which induces hot brittleness.

Steels intended for structures are distinguished by quality, application and smelting technique (open-hearth or converter steel).

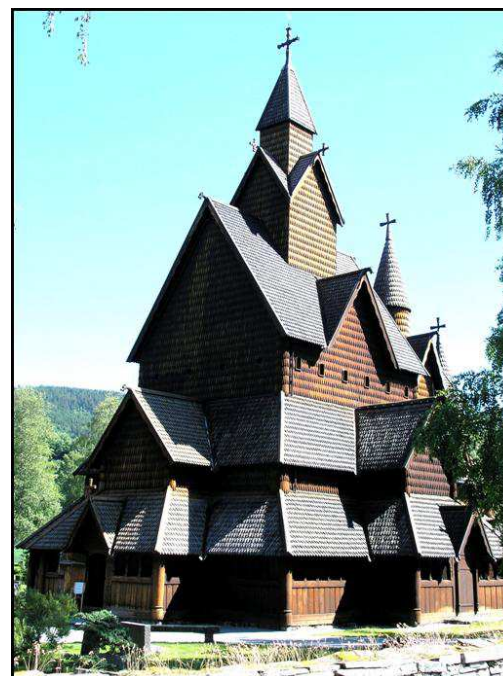
Mechanical and physical properties of steels (resistances to heat, abrasive wear and corrosion) are enhanced by admixtures of nickel (H), chromium (X), cobalt (K), copper (D), aluminum (A), silicon (C), manganese (Γ), etc, called alloying elements; corresponding steels are known as alloyed steels. Steels are considered low-, medium- and high-alloy when the contents of alloying substances are respectively below 2,5%, 2,5-10%, and over 10%. Low-alloy steels are widely used in construction practice. Alloyed steels, consist of structural, tool and special-kind varieties, the latter having a number of specific properties (stainless, acid-resistant; scale- and heat-resistant; and high electric-resistance).

The grade designation of an alloyed steel, for instance, 25X Γ 2C steel for reinforcing prestressed concrete, indicates that it contains 0,25% carbon, 1% chromium 2% manganese and 1% silicon. Thus, the first two figures indicate the content of carbon in hundredths of a per cent, and the figures that follow, the content in full per cent of the alloying element whose code letter precedes the figure.

3.4.3. Manufacture of Metallic Items and Constructions

Metallic items may be manufactured either by pouring molten iron or steel into specially shaped forms, called moulds, and then working ingots weighing from 500 kg several tons (sometimes tens of tons) by mechanical means or by direct casting the finished items of required shape, size and properties. Mechanical working is based on high plastic properties of metals. Practically, metals are rolled, forged, drawn, stamped and pressed.

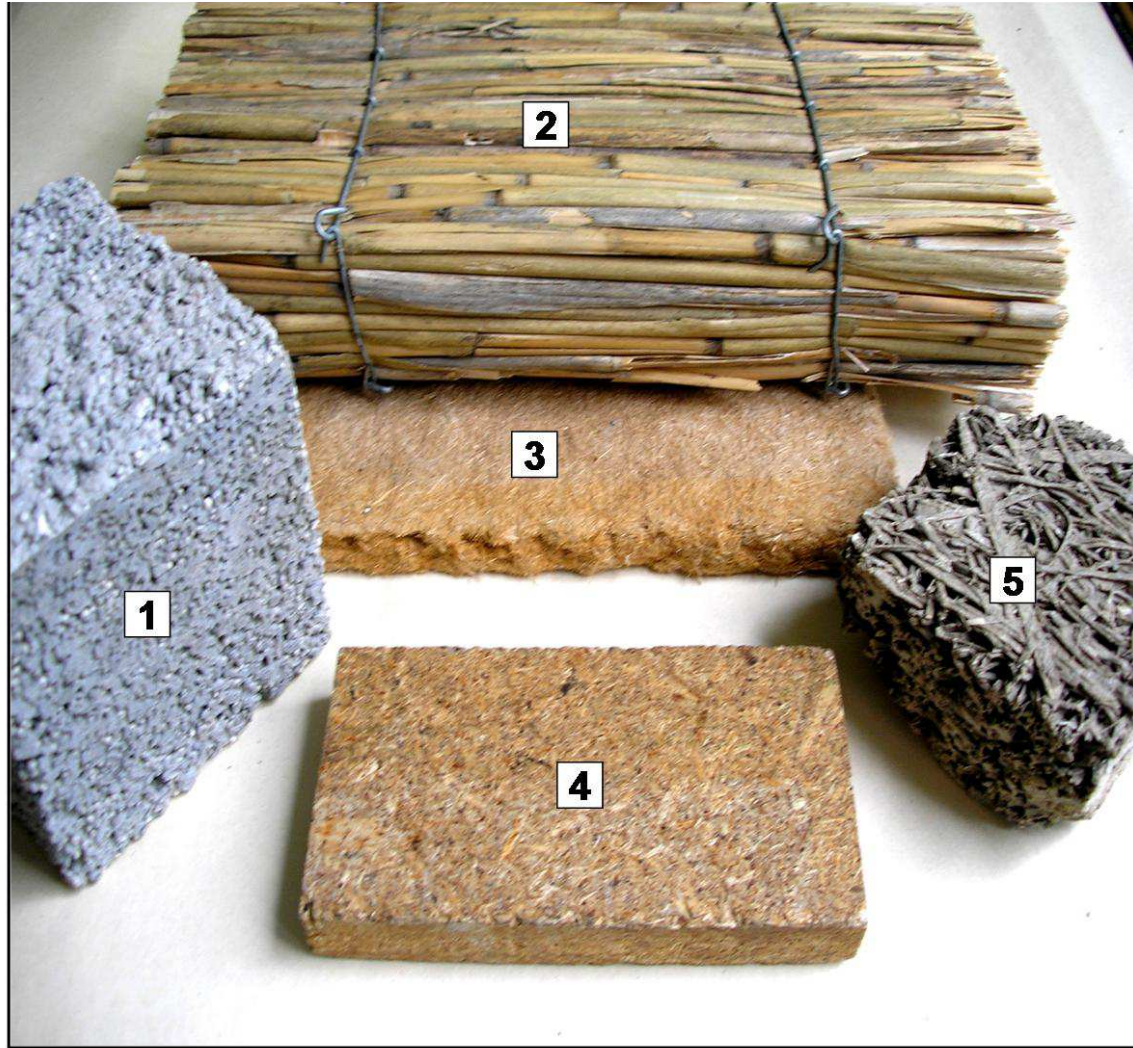
Rolling is a universal and cheap method of manufacturing metallic items. Rolling consists essentially in breaking down the metal between rotating rolls, the starting blank being reduced in cross section, drawn and given the shape of the rolls if the latter are not smooth. Metal is rolled cold or hot. Cold rolling is used for metals of high plasticity (lead, tin) or thinnest steel sheets (because they cool rapidly). Most steel items are generally hot-rolled at temperatures between 900 and 1250°C. A steel ingot is broken down to required shape in several successive steps by passing it through a number of roll pairs, each subsequent pair being set



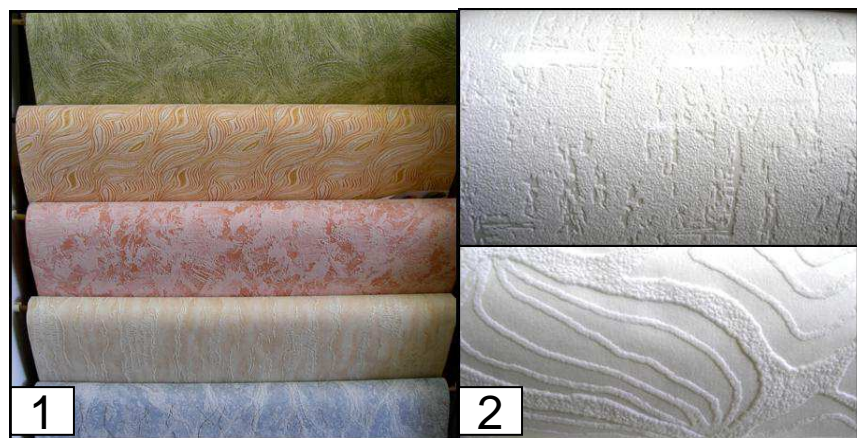
Pic. 1. Materials for walls from wood



Pic. 2. The use of reed as roof material



Pic. 3. Heat insulating and acoustic materials on the basis of wood fibre:
1 – arbolit; 2 – board of reed; 3 – wood fibreboard; 4 – wood chipboard; 5 – fibrolite



Pic. 4. Organic materials for finishing interior walls and ceilings:
1,2 – wallpaper; 3 – acoustic board from polymer materials;
4 – decorative veneer; 5 – panels from polymer materials.



1



3.1



2



3.2

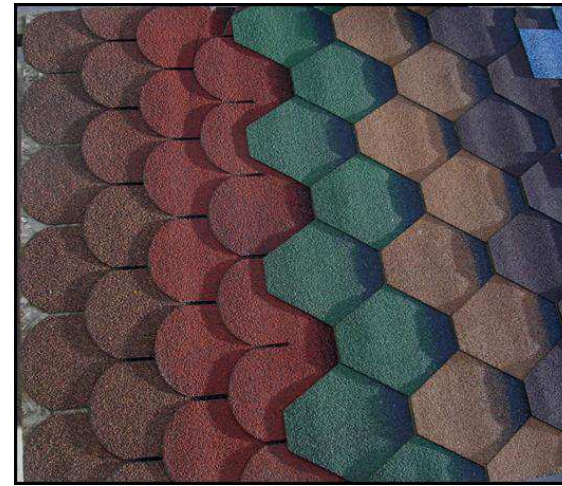
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Pic. 5. Organic materials for floor finishing:

- 1 – multilayer material from wood, protected with thin polymer film(laminates);
- 2 – roll material from polymer materials (linoleum);
- 3 – roll materials from wooden fibre (3.1) or polymer fibre (3.2)



Pic. 6. Heat insulating materials on the basis of polymers:
1, 2 – slabs; 3 – granulated



Pic. 7. Varieties and application of bituminous roofing roll materials on the basis of cloth glass



Pic. 8. Application of blocks and quarry stones in building practice (Rome)



Pic. 9. Application of blocks and quarry stones in building practice (Barcelona)



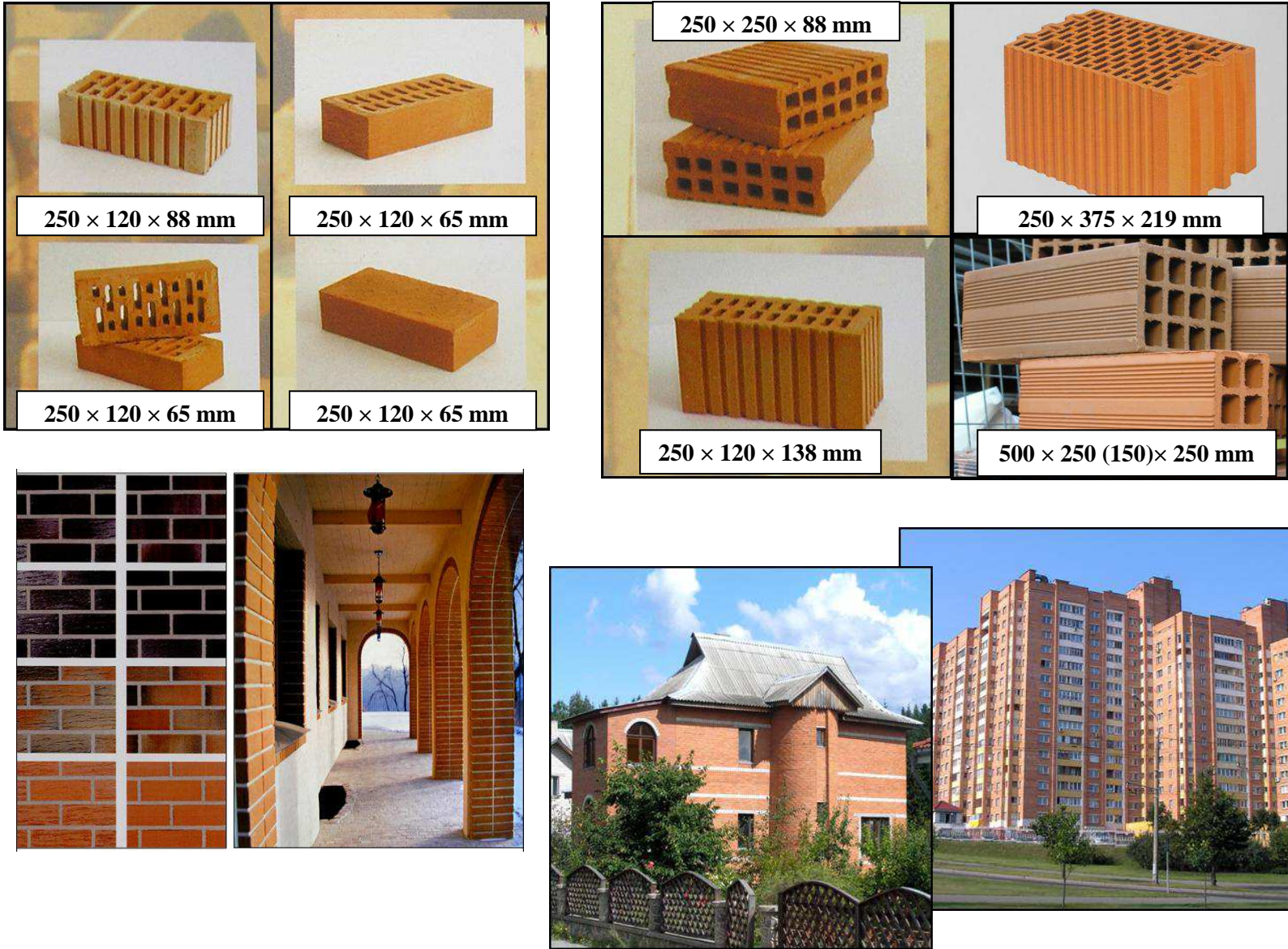
Pic. 10. Application of blocks and quarry stones in building practice (Andorra)



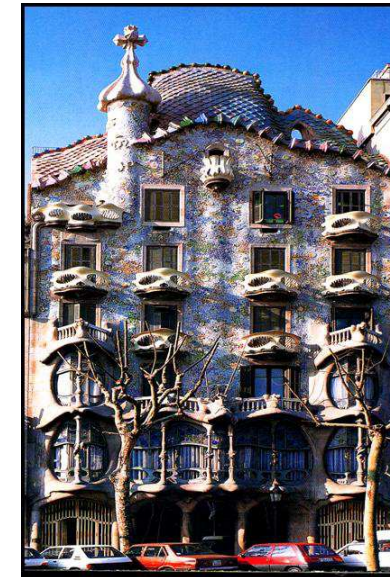
Pic. 11. Facing slabs for floors and interior walls from natural rock



Pic. 12. The roofing materials from clay shales



Pic. 13. Application of clay bricks, stones and blocks for outside walls



Pic. 14. Ceramic items for building facades



Pic. 15. Ceramic items for interior facing

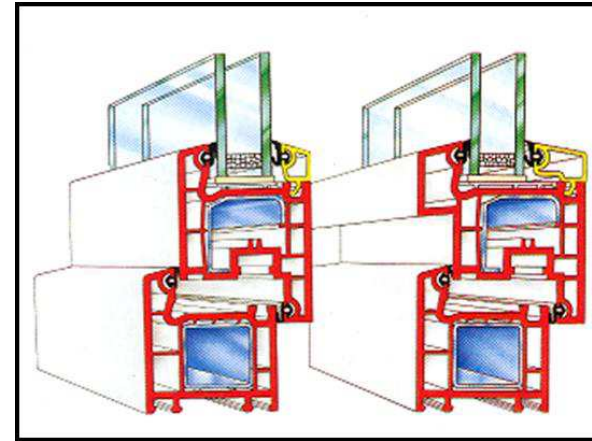


Pic. 16. Ceramic items of special use:

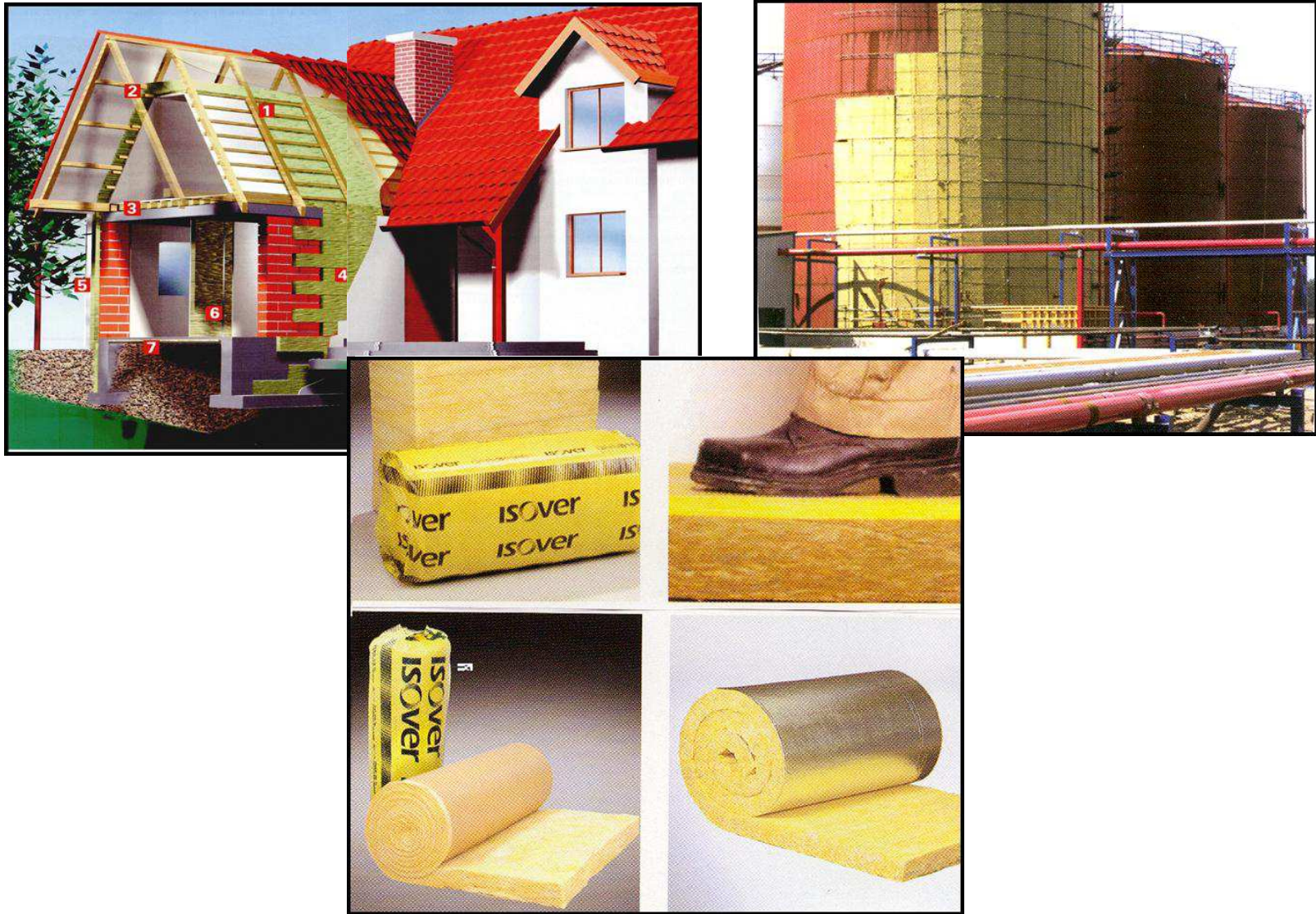
1 – acid resistant bricks and tiles; 2 – ceramsite, agloporit – heat insulating materials;
 3 – refractory materials; 4 – ceramic sewer and drainage pipes; 5 – sanitary ceramic items



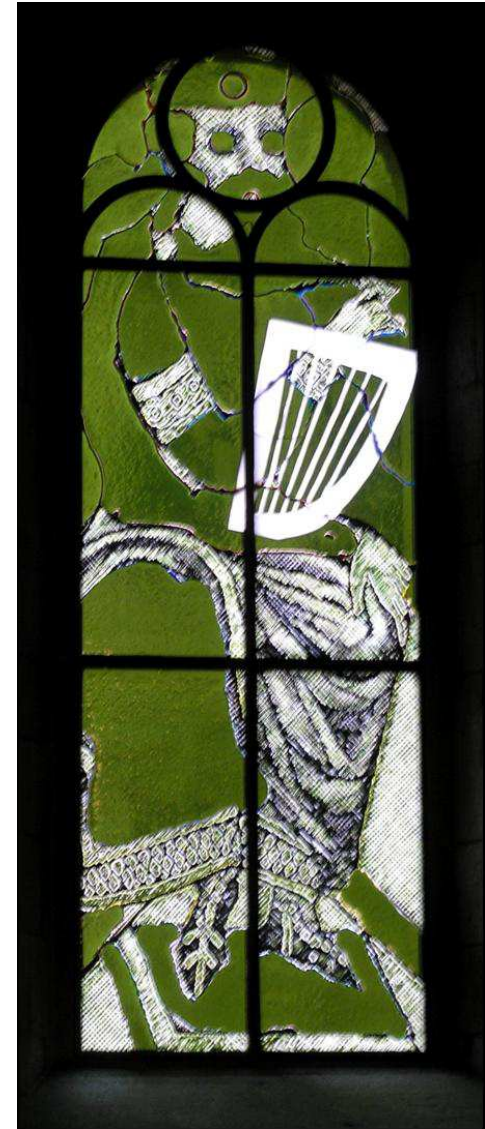
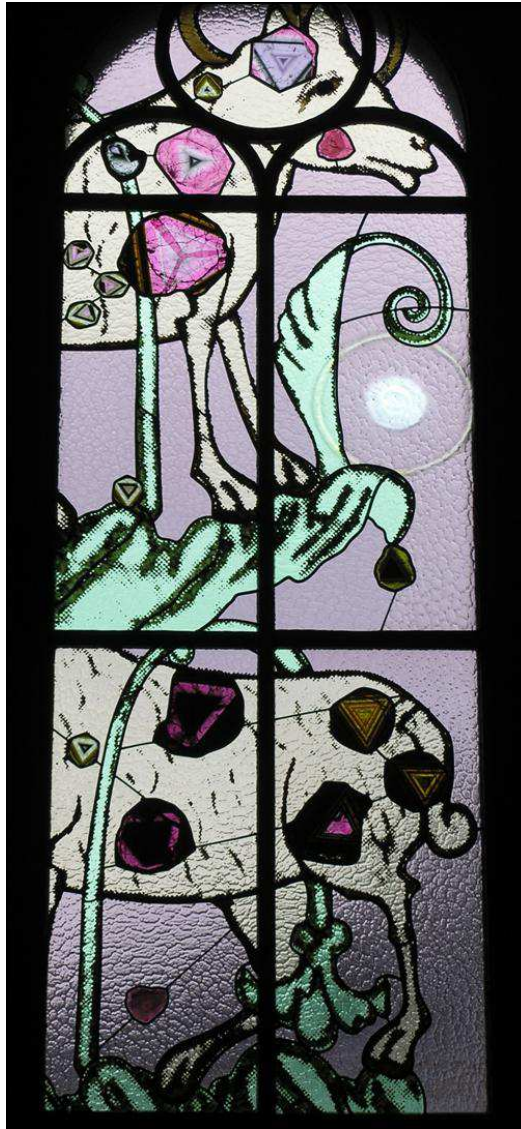
Pic. 17. Varieties of clay roof tiles



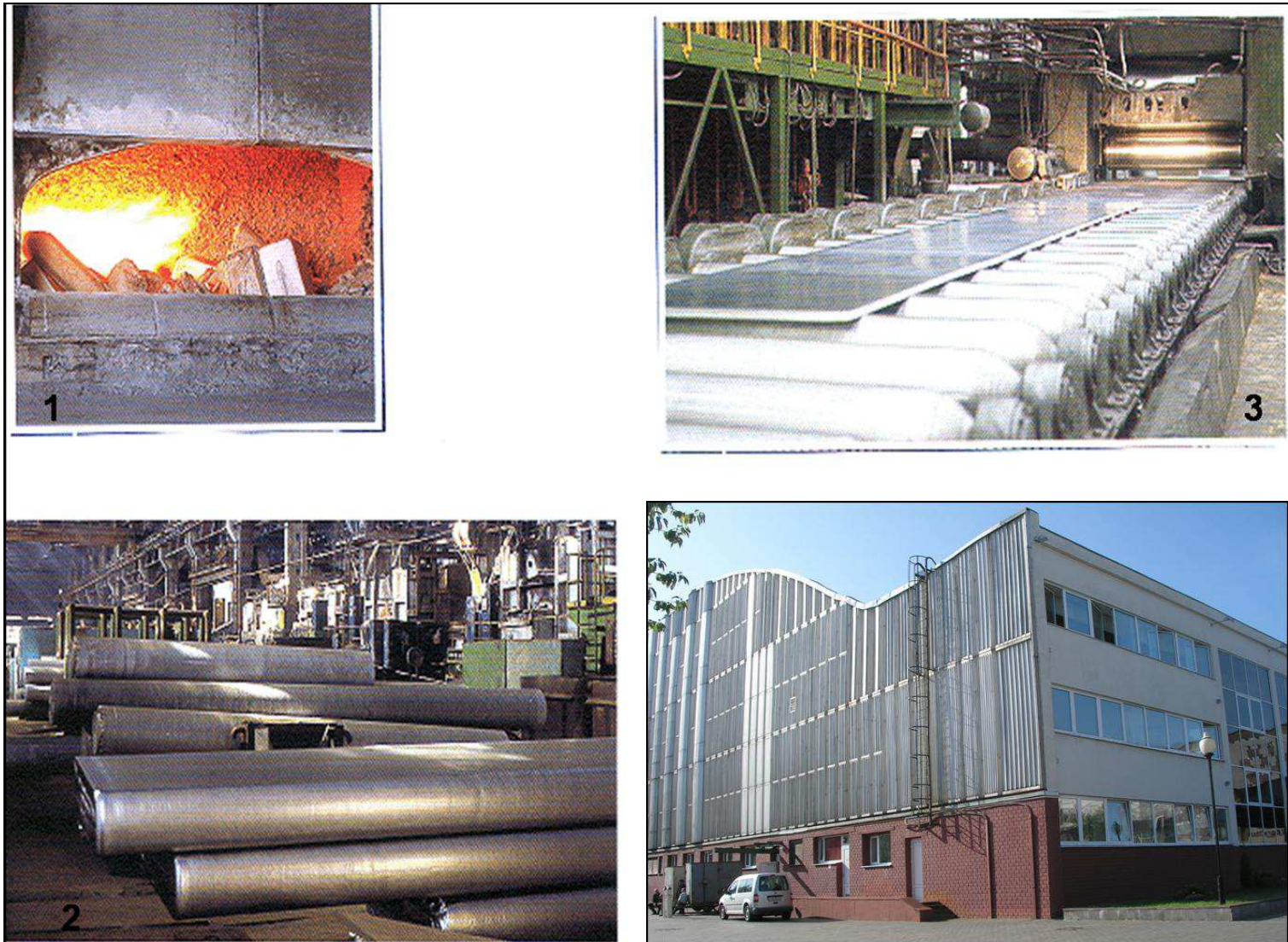
Pic. 18. Construction and application of glass slabs



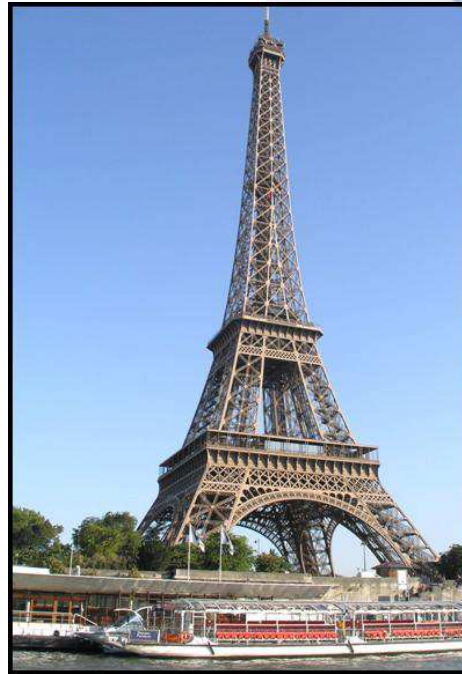
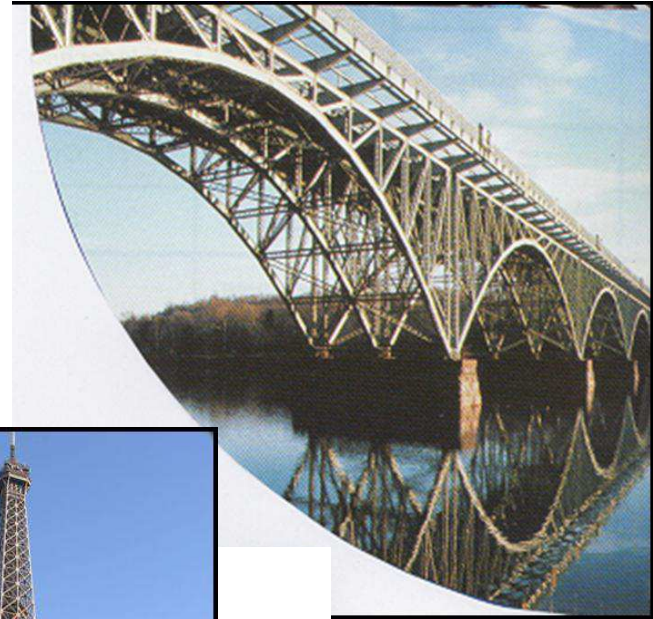
Pic. 19. Varieties of items from glass wool and their use



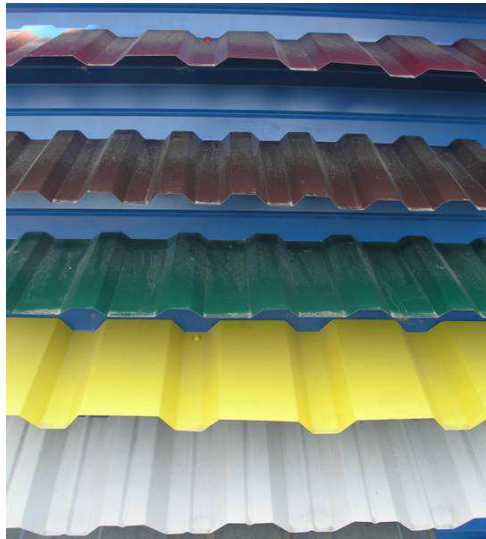
Pic. 20. The use of coloured glass



Pic. 21. Production and use of sheet steel



Pic. 22. Constructions from steel pipes and sections



Pic. 23. The use of sections from steel, protected with thin decorative polymer film for building facades and roofs



Pic. 24. The use of cellular lime-sand blocks and silicate brick for erecting walls



Pic. 25. Construction of the building from a monolithic reinforced concrete



Pic. 26. Construction of buildings from wall panels



Pic. 27. Varieties and application of cement-sand tiles as a protective decorative cover



Pic. 28. Varieties and application of cement-sand items for finishing floors, walls and pavements

closer to one another than the preceding one. Most of steel building components – beams, rails, steel leaves, bars, reinforcement, pipes – are manufactured by rolling.

Forging is deformation of metal by repeated strikes of a hammer or a press. Metal may be either forged free, when it is free to spread in all directions as it is hammered, or die-forged, when it flows under the blows of a hammer to fill the inside of a die, excess metal being forced out into a special groove and cut off. Die-forged parts have very accurate dimensions. In construction practice, free forging methods are generally used for the manufacture of various parts (bolts, cramps, anchor bolts).

Drawing is essentially pulling of metallic blanks through a drawing die orifice whose cross section is less than that of the blanks, with the effect that metal is reduced in cross section and given strictly the shape of the hole. The blanks are pre-rolled or pre-pressed bars or pipes. Metal is generally drawn cold, finished items being smooth and true to prescribed dimensions. Thin-walled items (tubes) and round, square, hexagonal rods of small cross-sectional areas (up to 10 mm²) are manufactured by drawing.

Drawing of metals results in work hardening, or increase in strength due to plastic deformation. Work hardening increases the hardness of steel, but lowers its plasticity and resilience. Cold working may cause steel fatigue, or structural changes which make steel brittle. On the other hand cold, working finds extensive practical use in mechanical strengthening of reinforcement steel with a view to raise its yield point.

Heat treatment provides steel items with specific mechanical properties such as high hardness (greater resistance to wear), low brittleness (improved machinability or impact strength), etc. This is achieved by heating and cooling the steel according to a strictly predetermined temperature schedule, with the effect that steel undergoes structural changes and acquires specific mechanical properties. There is a great number of heat treatment techniques, e.g., hardening, tempering, annealing, normalizing and case-hardening.

Hardening is heat treatment of steel involving heating to a predetermined temperature, holding for a time required for the completion of phase transformations and rapid cooling in water, oil and other liquids. Hardening enhances hardness and strength, but lowers resilience. Hardened steel is brittle and thus not suitable for practical use. To reduce brittleness and relieve internal post-hardening stresses, steel is tempered, i.e., heated to a temperature lower than that of hardening and then gradually cooled in the air. Depending on the kind of tempering, items are heated to 150-550°C. The greater the temperature of tempering, the greater are the changes in the mechanical properties of hardened steel: ultimate strength and hardness decrease, while relative elongation and resilience increase.

Annealing reduces heterogeneity in the structure of steel, gives it a fine – grained texture, relieves stresses from mechanical working (forging, drawing) or founding and improves the machinability of steel.

Normalizing is essentially an annealing process. Steel items are heated to and maintained at a temperature somewhat below the hardening point, then cooled in the air. The effect is a more fine-grained, harder, stronger, and more resilient steel than that after annealing.

Case-hardening of steel consists in changing the chemical composition of the surface layer of a steel item by saturating it with certain substances such as carbon, nitrogen, chromium with a view to enhance hardness, wear resistance or corrosion resistance of the item's skin, while retaining the high mechanical properties of its interior core.

Cementing of a steel part consists in saturating its skin with carbon. This is achieved by heating the item to a temperature between 880 and 950°C in a carbon rich medium.

Nitriding consists in saturating the surface layer of a steel item with nitrogen by heating it to a temperature between 500 and 700°C in an atmosphere of NH₃; the treatment enhances the steel corrosion resistance, hardness, wear and fatigue resistance. The nitride layer is from 0,01 mm to 1,0 mm thick.

Resistance of steel to corrosion by fresh and sea water, nitric acid, oxidizing atmosphere (resistance to scaling) is improved by chroming i.e., saturation of its surface layer with chromium.

Such steel items as rivets, bolts, nuts, washers, screws, nails, forgings, steel cables and steel are reinforcement for concrete. Rivets are used for fixed joints of metallic structures and bolts and nuts, for detachable joints.

Concrete is reinforced with steel elements or complete frameworks set inside the body of a concrete component. Reinforcement is generally placed at points of a structure that are subject to tensile stresses (members in bending, tension, off-centre compression). Reinforcement is a major component of reinforced concrete and it is required to show reliable service together with concrete at all stages of the latter's life. Effectiveness of concrete reinforcement may be enhanced by the use of low-alloy steel, the alternative being mechanical strengthening (drawing, stretched, twisting) or heat treatment. Reinforcement steel is classified by manufacturing methods, cross-sectional shape and application.

By manufacturing methods, reinforcement steel is available in hot-rolled bar and cold-rolled wire varieties intended for reinforcing common non-prestressed and prestressed structures. By cross-sectional configuration (character of surface), bar and wire reinforcement is divided into plane and die-rolled

types. Bar reinforcement is available in the following types: hot-rolled; strengthened by heat treatment and drawing; strengthened by cold drawing after rolling. Wire reinforcement (diameters from 3 to 8 mm) is subdivided into reinforcement wire and prefabricated wire. There are two classes of reinforcement wire: cold-rolled (low-carbon) intended for non-tensioned reinforcement and carbon intended for prestressed reinforcement (high-strength reinforcement wire).

Reinforcement wire, items are subdivided into: steel reinforcement cable, two- and multi-strand, intended for prestressed reinforcement; welded wire mesh reinforcement for non-prestressed work; woven or welded wire mesh for strengthening asbestos-cement constructions.

Inserts are intended for welding together separate reinforced concrete items, when erecting reinforced concrete constructions. These parts are steel plates with welded-on anchors from die-rolled steel. The plates are situated on the surface, while the anchors are inside the body of concrete. Sometimes anchors are connected to the reinforcement to provide greater strength. Handling loops placed into concrete are manufactured from smooth round steel, whose diameter is calculated according to the ultimate strength of the loop and the effort required to pull the loop out of concrete.

Steel constructions are generally joined together by spot or electric arc welding, gas and thermit welding techniques being seldom used.

Concrete reinforcement is welded mainly by spot welding (resistance butt and spot welding). Large-size three-dimensional frame-works and large-diameter bars are joined together by electric arc and gas welding.

Gas welding is essentially fusion of metals at their joints by the heat released by gas or liquid fuel burning in oxygen.

The joint between the welded parts is filled with a wire metal, close in chemical composition to the metals being welded.

Electric welding is effected at the expense of the heat released by the electric current and is subdivided into resistance (spot) welding and electric arc welding.

Electric spot welding is used for joining metallic parts by forcing them one against the other and passing an electric current which releases heat at the joint. This is why the technique is sometimes called electromechanical welding. It is used chiefly in the manufacture of reinforcement wire meshes and carcasses and for joining steel bars.

In electric arc welding, one conductor from a power source is connected to a part being welded, and the second, to the welding electrode (metal rod). The closing of the circuit between the electrode and the part being welded produces an electric arc with a temperature of 6000°C fusing together edges of the parts and the electrode, the metal of the electrode fills the gap between the parts and produces a welded seam whose strength depends on the depth of penetration.

3.4.4. Nonferrous Metals and Alloys

Nonferrous metals and alloys are used on an ever increasing scale in the manufacture of building components of high engineering properties. Aluminium alloys, that were subsequently developed, rapidly replaced carbon-metal alloys with great engineering and economical advantages. Alloys of copper, zinc, lead, tin, manganese find use in special kinds of building work.

Aluminium alloys are widely used for the manufacture of rolled sections, such as angles, channels, round and rectangular pipes. Aluminium alloys are much used for the manufacture of rivets bolts and sheets. Items manufactured of aluminium alloys are easy to produce, pleasing in appearance, resistant to seismic action and cold, feature good fire-resisting and antimagnetic properties and durability, which makes them competitive with steel and other construction materials. The scope of application of aluminium constructions and semi-products is being at present expanded by developing structural-and facing materials with various protective-ornamental coats of polymer, varnish, paint, enamel, and electrolytic types. Aluminium structures are being widely introduced in civil, industrial and farm constructions.

Copper alloys are used for any practical building purposes in the form of brasses and bronzes. Brass is an alloy of copper and zinc (up to 40%) and bronze – an alloy of copper with tin or any other metal except zinc. Brasses and bronzes many important engineering properties, they are adequately strong (300 to 600 MPa), can be produced with high surface hardness (HB from 200 to 500), have excellent corrosion resistance. Copper alloys are used in construction work only for the manufacture of sanitary ware (stop cocks, valves) and in special cases for finishing and decoration purposes.

Lead and zinc find much wider use in construction work. Zinc is chiefly used for roofs, cornices and drain pipes. Zinc resists corrosion by surrounding media. Lead applications include lining of acid-resistant chemical apparatus, special kinds of waterproofing and also as screens for protection of radiation.

3.5. Mineral Binders Substances

Mineral binders are fine powders that are capable of producing a plastic pasty mass on mixing with water and passing into a stony state when exposed to physical and chemical action. This property makes the binders suitable for the preparation of mortars, concretes (mixtures of binders, water and aggregates such as sand crushed stone or gravel) artificial cast stone materials and items.

Mineral binders are subdivided into air-setting and hydraulic setting varieties.

Air-setting binding materials are substances that pass into a stone state, gaining and retaining mechanical strength in the air only. Representatives of air-setting binding materials are gypsum, magnesian binding materials, air-hardening lime and acid-resistant cement.

Hydraulic-setting binding materials are substances that pass into a stone state, gaining and retaining strength not only in the air, but in water as well. The group of hydraulic-setting binding materials includes Portland cement and its varieties, puzzolana and slag binding materials, alumina and expanding cements, hydraulic lime and Roman cement. They are used in above and below-ground and underwater constructions.

Distinction is made of autoclave-setting binding material, which set only when treated in autoclaves with saturated steam at pressures from 0,8 to 1,2 MPa and temperatures between 170 and 200°C. They fall into the autoclave-setting group are lime-silica and lime-slag binders.

3.5.1. Air-Setting Binding Materials

Gypsum binding materials

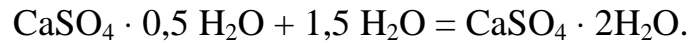
The source materials for the manufacture of gypsum binding materials are natural gypsum rock $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ and natural anhydrite CaSO_4 , as well as chemical industry waste containing dehydrate or anhydrous calcium sulphate, e.g., phosphorous gypsum.

Gypsum binders are subdivided into two groups: low- and high-burning varieties. Low-burning gypsum binders are obtained by heating dehydrate gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) to a temperature of 150-160°C; dehydrate gypsum is partially dehydrated and converted to semihydrate gypsum ($\text{CaSO}_4 \cdot 0,5\text{H}_2\text{O}$) – building and extra strong gypsum. High-burning (anhydrite, estrich gypsum) binding materials are obtained by burning dihydrate gypsum at a higher temperature (700-1000°C) to a complete loss of chemically bound water and formation of anhydrous calcium sulphate, the anhydrite (CaSO_4). Building and extra strong gypsum fall into the low-burning category, and the anhydrite cement and the estrich gypsum, into the high-burning category.

Building gypsum

The manufacture of **building gypsum** involves crushing, grinding and thermal processing (dehydration) of gypsum rock ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). The obtained building gypsum ($\text{CaSO}_4 \cdot 0,5\text{H}_2\text{O}$) is then finely ground in mills.

When water is added to gypsum powder, the semihydrate calcium sulfate $\text{CaSO}_4 \cdot 0,5\text{H}_2\text{O}$ contained in the latter dissolves until a saturated solution is formed; at the same time, said semihydrate hydrates by taking up 1,5 molecules of water and converts to dihydrate $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ according to the reaction



The solubility of the dihydrate is approximately one-fifth that of the initial powder, the semihydrate $\text{CaSO}_4 \cdot 0,5\text{H}_2\text{O}$, with the effect that the resultant saturated solution of the semihydrate is found to be supersaturated with respect to the dihydrate. The supersaturated solution cannot exist under the ordinary conditions and gives a very fine precipitate, the dihydrate calcium sulfate. The fine particles accumulate, bond together to cause the thickening (setting) of the pulp, then crystallize to form a strong gypsum stone. A further increase in the strength of gypsum takes place through the drying of the setting mass and its further crystallization.

Building gypsum is a quick setting and quick hardening binder. Setting of building gypsum should begin not earlier than in 2 min and end not earlier than in 6 min and not later than 30 min after it has been mixed with water. The prescribed fineness of building gypsum in terms of the total retained on sieve № 02 (size of sieve mesh is 0,2 mm in the clear) is as follows: for grade I, up to 23%, for grade II, 14% and for grade III, up to 2%. The finer the size content of gypsum, the greater is its strength. The bending strength of specimen bars measuring 4×4×16 cm 2,0 hours after mixing of gypsum with water should be 1,2-8 MPa. The compressive strength of the halves of specimen bars should be 2-25 MPa respectively.

The very rapid setting of gypsum makes it difficult to use it for some purposes and calls for setting retarders special additions, in amounts from 0,1 to 0,3% of the weight of gypsum.

Common building gypsum is obtained by heating natural gypsum rock at normal pressure, fine crystals of semihydrate calcium sulphate being formed under these conditions (β – modification). The resultant gypsum is very hygroscopic (60-65%) water. The excess water, i.e. beyond the amount necessary to hydrate gypsum (15%), evaporates and leaves pores, with the effect that hardened building gypsum has a high porosity (up to 40%), and, therefore, a low strength.

Extra-strong gypsum

Heating of natural gypsum by steam at a pressure of up to 0,2-0,3 MPa followed by drying at 160-180°C. The process results in the formation of larger crystals, the effect being a lower hygroscopicity (40-45% water) and gypsum

stone of greater density and strength. This type of gypsum is called **extra-strong**: in 7 days it attains a strength of 15-40 MPa. Low-burning gypsum binders ($\text{CaSO}_4 \cdot 1,5\text{H}_2\text{O}$) are used for the manufacture of gypsum and gypsum-concrete structural items for interiors of buildings (partition slabs panels, plaster boards), for preparing gypsum and complex mortars and for the manufacture of ornamental and finishing materials (e.g., artificial marble).

Anhydrite cement

Anhydrite cement is obtained by burning natural dihydrate gypsum at a temperature of 600-700°C and then grinding the product together with hardening catalyzers (lime, slag, etc.). Anhydrite cement can also be obtained by grinding natural anhydrite with the above additives. Anhydrite cement is a slowly setting binder; its setting starts not earlier than in 30 min and ends not later than in 24 h. By compressive strength, this cement is available in grades 5, 10, 15 and 20 (MPa). Anhydrite cements are used for preparing bricklaying and plastering mortars, concretes, heat insulating materials, artificial marble and other ornamental items.

Estrich gypsum (high-burned gypsum)

A variety of anhydrite cements is the **estrich gypsum**. It is manufactured by burning natural gypsum or anhydrite at a temperature between 800 and 1000°C followed by fine grinding. This results not only in complete dehydration but also in partial decomposition of anhydrite with the formation of CaO (3-5%) according to the reaction $\text{CaSO}_4 = \text{CaO} + \text{SO}_3$. When estrich-gypsum is mixed with water, CaO acts as a catalyzer which promotes the hardening of the anhydrite cement in a manner discussed above. Estrich gypsum is used to prepare bricklaying and plastering mortars, to build mosaic floors, to manufacture artificial marble, etc. Items from high-burned gypsum have low heat and sound conductivity, higher frost and water resistance and a smaller tendency to plastic deformation than products from building gypsum.

With aim at importing hydraulic properties to gypsum binders its mix with Portland cement and active mineral addition (puzzolana or blast furnace slag). The resultant binders (**gypsum + cement + puzzolana – GCPB, and gypsum + cement + slag – GCSB**) are classed with the hydraulic variety. These varieties binders are used for preparing floor bedding, internal wall panels, and for pre-fabricating toilet and washroom units and other items, which can be used for work in humidity conditions.

Gypsum-based products can be obtained both from gypsum paste, i.e., from a mixture of gypsum and water, as well as from a mixture of gypsum, water

and aggregate. The former are called gypsum, and the latter, gypsum-concrete products. Gypsum and gypsum-concrete items are manufactured from building or high-strength gypsum, water-resistant gypsum-cement puzzolana mixes and anhydrite cements. Aggregates in gypsum concrete are artificial materials (sand, pumice, tuffs) and industrially manufactured lightweight porous aggregates (slag pumice, ceramsite gravel, sinter, etc). Organic aggregates are sawdust, shavings, paper waste, stalks or fibres of cane reed, refuse of dressed flax, etc.

Highly porous heat-insulating items are manufactured from gypsum mass by introducing gas-forming or foam-forming agents.

Although it possesses a number of valuable engineering properties, gypsum is very brittle. Therefore, gypsum items are artificially strengthened by reinforcing (fibrous) materials that are introduced into the moulding mass or are part of the item, itself. Thus the reinforcement in the plaster board is the outside cardboard envelope, whereas that in rolled partition gypsum-concrete panels is the wooden lath carcass. Metal bars, wire or wire mesh may also be used as reinforcement, but it should be borne in mind that steel reinforcement in gypsum items is susceptible to corrosion and so requires a protective coat. Organic fibres, uniformly distributed throughout the body of a moulded item may also serve as reinforcement.

According to their application, gypsum and gypsum-concrete items are subdivided into partition panels and slabs, facing sheets (gypsum plaster and gypsum fibre plaster boards), heat-insulating slabs, floor items, refractory fire-resisting items, architectural items. Gypsum items can be either solid or hollow, reinforced or non-reinforced.

Gypsum items have a number of valuable properties, such as relatively small bulk density; they are incombustible good sound absorbers, etc. Among their shortcomings one should mention poor strength in wet state and high creep under load, particularly in moist surroundings. Therefore, gypsum-based items should be used only in dry state and in premises of not more than 60% relative air humidity. To improve moisture-resistance and water-resisting properties of gypsum items, the latter are coated with waterproof paints, an alternative technique is to add gypsum cement-puzzolana or gypsum-cement-slag binding material.

Gypsum and gypsum-concrete items are moulded by various methods, such as casting. Vibrating, pressing, rolling, in the process of which they acquire considerable strength.

The process of manufacture of items from gypsum or gypsum-concrete involves the following operations: proportioning of ingredients (binding material, aggregates, water and materials affecting the setting time); preparing mortar or concrete mixes; moulding items; hardening items by drying them to air-dry state.

Building lime

Building lime(CaO) is produced by burning (to eliminate carbon dioxide) calcium-magnesium rocks such as limestone – CaCO_3 , dolomite – $\text{CaCO}_3 \cdot \text{MgCO}_3$ containing less than 6% clay impurities. Lime manufacture consists in quarrying and preparation (crushing and screening) of rocks and its burning. The temperature of limestone burning is set generally between 1000 and 1200°C, with due regard for limestone density, content of impurities.

The main stage in lime manufacture is burning in which limestone decarbonizes and turns into lump lime according to the reaction



After burning lump lime is ground to unslaked, powder lime or is slaked with water to yield slaked lime.

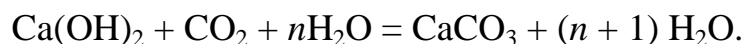
As specified in the State Standard content of active $\text{CaO} + \text{MgO}$ in unslaked lime should be 50-90%, ground to a fineness of not more than 1,5 and 15% oversize on screens № 02 and 008, respectively.

Air-hardening lime differs from other binders in that it may be powdered not only through grinding, but also through slaking, or the action of water upon lumps of unslaked lime with a release of a considerable amount of heat according to the reaction (kJ)



Depending on its slaking rate, air-hardening lime is divided into the following kinds: rapid slaking lime with a slaking time of not more than 8 min; medium-slaking lime, of up to 25 min; slowly-slaking lime, of not less than 25 min.

The hardening of lime mortars thus results from their drying and forming a crystalline aggregate Ca(OH)_2 , and from the crystallization of calcium carbonate on the surface of items to the reaction



Ground unslaked lime may be used as such, this presenting a number of advantages: no unslaked grains of lime are lost; the heat released by the hydration of lime speeds up the setting and hardening processes. Items from this kind of lime are denser, stronger and more water-resistant. Slaked lime hardens slowly and the strength of lime mortars is low.

Calcium oxide hydrate crystallizes the faster the greater the evaporation of water, and therefore an above-zero temperature is essential for the hardening of lime.

Air-hardening lime is widely used in the preparation of mortars for bricklaying and plastering and also as painting compositions. Lime is used in the manufacture of lime-puzzolana, lime-sand and lime-slag hydraulic binding materials. This binding is used for receipt of artificial stone materials, such as lime-sand brick and slabs large-size items from lime-sand concrete cellular lime-sand items.

Under natural conditions sand in a lime-sand mixture is an inert material incapable of interacting with lime, with the effect that the strength of the mixture is due primarily to the hardening of lime. However, in a steam-saturated atmosphere (100% humidity), steam curing at a pressure of 0,8 MPa and temperature of 170-203°C (autoclave hardening), sand silica becomes chemically active and quickly combines with lime and consequently forms calcium hydrosilicates of great strength and high water-resisting properties. Lime-sand mixtures serve for manufacturing silicate large-size prefabricated items (blocks and panels for floors and walls) such as silicate brick and wall stones, as well as slabs for facing facades.

Silicate brick is similar in shape, size and chief applications to clay brick. Lime-sand brick should not be used for foundations and pedestals because it is less water-resistant than clay brick. This brick is not suitable for furnace brick work, since prolonged exposure to high disintegration.

Lime-slag and Lime-Ash brick are a variety of silicate brick, but differ by a lower bulk density and better heat insulating properties. These items are used for erecting walls of low (up to three storeys) buildings and walls of upper storeys of multi-storey buildings.

Lime-sand concrete is an autoclaved and compacted mix composed of quartz sand (70-80%), ground sand (8-15%) and ground unslaked lime (6-10%). Dense lime-sand concrete is a variety of heavy concrete. Large-size lime-sand items have a compressive strength of 15-60 MPa; bulk density, of 1800-2300 kg/m³; frost resistance, of 50 cycles and over. Dense lime-sand items are used for residential, industrial and public building construction; they should not be used for foundations and other structures exposed to high humidity.

Facing materials are the subject of two essential requirements – durability and high ornamental qualities. These requirements are met by lime-sand slabs which are pure white or can readily be coloured by mineral alkali-resisting pigments. Lime-sand facing slabs are manufactured from mixes of ground unslaked lime and quartz sand. Lime-sand facing slabs can be used for finishing brick walls of residential, public and industrial buildings, except for buildings of a high relative humidity of premises (bath houses, laundries, etc). The slabs should not be used for facing pedestals, parapets, exterior window sills, belt courses and other projecting parts of buildings, exposed to rain and thawing snow, unless adequately protected by waterproof coats.

Lime-sand items of cellular, structure feature low bulk density and heat conductivity. Cellular lime-sand items are available in two kinds – foam and gas lime-sand. Foam lime-sand items are manufactured from a mixture composed of lime up to 25% and ground sand (sometimes part of the sand is unground). Ground sand may be replaced by ground slag and cinder. Gas lime-sand items of cellular structure are formed by introducing aluminium powder into a prepared mixture. Items from cellular concretes are manufactured with and without reinforcement (pic. 24).

In the reinforced silicate (lime-sand) concretes, the steel reinforcement and the inserts are susceptible to greater corrosion than in cement concretes. To remedy this, the reinforcement bars in the cellular items are coated with cement-casein and polymer-cement compositions, or metallized. Cellular lime-sand items are generally used for outside walls of buildings, partitions and also for roofs of industrial buildings where the load-supporting and heat-insulating properties of cellular concrete are utilized to their full advantage.

Magnesian binding materials

Caustic magnesite (MgO) and caustic dolomite (a mixture of MgO and CaCO₃) are two varieties of magnesian binders.

Caustic magnesite is obtained by burning magnesite rock MgCO₃ in shaft or rotary furnaces at temperatures of 650 to 850°C, with the effect that MgCO₃ decomposes according to the reaction $MgCO_3 = MgO + CO_2$.

The solid residue (magnesium oxide) is ground to fine powder.

Caustic dolomite is obtained by burning natural dolomite (CaCO₃ · MgCO₃) and grinding the product to fine powder. As dolomite is burned, CaCO₃ is not decomposed and remains inert as a ballast, thus reducing the binding activity of caustic dolomite as compared to caustic magnesite.

Magnesian binders are mixed not with water, but with aqueous solutions of magnesium sulphate or chloride for to accelerating of the setting.

Caustic magnesite hardens relatively fast. It should begin to set not earlier than 20 min and harden not later than 6 h from the time it is mixed. Caustic magnesite is available to the compressive strength in grades 40 MPa through 60 MPa after 28 days of ageing in the air. Caustic dolomite is available in grades from 10 MPa to 30 MPa.

Magnesian binders, being air-setting, have a poor resistance against water. They may be used only in an atmosphere of a relative humidity of not more than 60%. Xylo-lite (a mixture of sawdust and binders), used to make floors, as well as fibrolite and other heat-insulating materials, are manufactured from magnesian binders which are also used for fabricating items for interior facing of buildings, subflooring, sculptures.

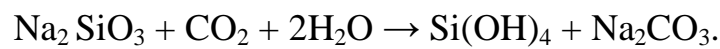
Acid-resistant cements

Acid-resistant cements consist of an aqueous solution of sodium silicate (soluble glass), an acid-resistant aggregate and an additive (hardening accelerant). The microaggregates are quartz, quartzites, andesite, diabase and other acid-resistant materials; the hardening accelerant is sodium fluosilicate.

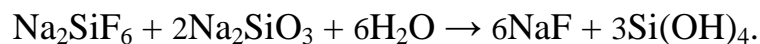
The binding material in the acid-resistant cement is soluble glass – a water solution of sodium silicate $\text{Na}_2\text{O} \cdot n\text{SiO}_2$ or potassium silicate $\text{K}_2\text{O} \cdot n\text{SiO}_2$.

Soluble glass is melted from quartz sand, ground and thoroughly mixed with soda ash, sodium sulphate or potassium carbonate in glass tanks at a temperature between 1300 and 1400°C. Melting takes from 7 to 10 h. The resultant glass mass flows from the furnace into cars where it cools rapidly and breaks up into pieces called “silicate lumps”. This glass is soluble in water under normal conditions, but when exposed to the action of high-pressure steam (0,5-0,6 MPa at about 150°C), it fairly readily becomes liquid.

Soluble glass hardens in the air because atmospheric carbon dioxide causes amorphous silica $\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ [$\text{Si}(\text{OH})_4$] to settle out and dry according to the reaction



But this process is very slow in the air. Hardening of soluble glass is accelerated by adding a catalyzer sodium fluorosilicate (Na_2SiF_6) which interacts rapidly with soluble glass to produce a silicate gel



Soluble glass is used for preparing acid-resistant and heat-resistant (to 1000°C) coatings, mortars and concretes. It should not be used in constructions subjected to the action of water, alkalis and phosphoric, hydrofluoric or fluosilicic acids for long periods of time.

3.5.2. Hydraulic Binders

Hydraulic lime and Roman cement

Hydraulic lime is a fine powder product of moderate burning (at temperatures between 900 and 1100°C) of marly limestone containing from 6 to 20% of argillaceous impurities; part of CaO resulting from the decomposition of calcium carbonate combines in solid state with oxides $\text{SiO}_2 \cdot \text{Al}_2\text{O}_3$ and Fe_2O_3 contained in the clay minerals, to form silicates ($2\text{CaO} \cdot \text{SiO}_2$), aluminates

(CaO · Al₂O₃) and calcium ferrites (2CaO · Fe₂O₃) that are capable of hardening not only in the air, but in water as well.

Since hydraulic lime contains free calcium oxide CaO, it slakes like air hardening lime upon contact with water. The more is the amount of free CaO in hydraulic lime, the less is its ability to harden in water.

The commercial lime is generally characterized by the hydraulic or the basic modulus (BM) whose value for hydraulic lime ranges from 1,7 to 9 as calculated by the formula below

$$BM = \frac{CaO}{SiO_2 + Al_2O_3 + Fe_2O_3},$$

where – CaO, SiO₂, Al₂O₃, Fe₂O₃ are measured in %.

Hydraulic lime is available in two kinds: a weak hydraulic lime with a modulus of 4,5 to 9 and strong hydraulic lime with a modulus of 1,7 to 4,5. If the burning product has a hydraulic modulus of less than 1,7, it is referred to Roman cement ($m = 1,1$ to 1,7), and greater than 9, to air-hardening lime.

Hydraulic lime, after it is mixed with water and begins to harden in the air, continues to harden in water as well, in which case the physical and the chemical air-hardening processes combine with those of the hydraulic hardening. As water evaporates, calcium oxide hydrate gradually crystallizes and also carbonizes due to the carbon dioxide of the air.

The hydraulic hardening of lime takes place through hydration of silicates, aluminates and ferrites of calcium in the same manner as in Portland cement. Compressive strength of slab specimens, 40 × 40 × 160 mm in size made of a plastic mortar composed of 1 part of Portland cement and 3 parts of hydraulic lime and 3 parts of sand (by weight) and tested 7 days in the air and 21 days the hydraulic hardening of 2,0 (weak hydraulic lime) to 5,0 (strong hydraulic lime) MPa.

Hydraulic lime is used for preparing construction mortars intended for service in dry or moist surroundings, as an admixture to lower grades of concretes.

The manufacture of Roman cement consists in quarrying marl which contain not less than 25% of clayey impurities, crushing it to lumps of a specified size, burning it (from 1000 to 1100°C) and, finally, grinding the burnt material.

Burnt material is best ground in ball mills with an admixture of gypsum and active mineral agents, as this yields a more uniform product.

Setting and hardening of Roman cement involves the hydration of calcium silicates and aluminates, which are the main constituents of Roman cement.

Roman cement should set in 15 min and harden not later than 24 h after it has been mixed with water.

Roman cement is a slow hardening binder with relatively low strength grades of 2,5; 5,0 and 10,0 MPa.

Roman cement is used for plaster and bricklaying mortars, low grade concretes, manufacture of wall stones and smaller slabs, in particular of steam-treated ones.

Portland cement

Portland cement is a hydraulic binding material which hardens in water and in the air. It is manufactured by fine grinding of a mixture of limestone (1 part), and clay (3 parts by weight) that has been burned until the components have caked (temperature of about 1500°C), presence of clay ensures the predominance of calcium silicate in the clinker, which is mixture of raw materials burned to fusion and composed of grains up to 40 mm in size.

There are two chief techniques for manufacturing Portland cement: the wet and the dry methods, which differ by the manner of preparing the raw material mixture. In the wet method the source materials are ground and mixed in the presence of water, and the mixture is burned in the form of a pulp (slime of liquid consistency); in the dry method, the materials are ground, mixed and burned dry. Along with the two main techniques, there is an increasing trend to use a combined method, which incorporates the advantages of the dry and the wet methods. According to this technique, the raw mixture is prepared by the wet method, then slime is dewatered and processed to granules which are burned by the dry method.

The hot clinker thus obtained is transferred to a cooler, where it is rapidly cooled by a countercurrent of cold air. Clinker is ground together with admixtures gypsum and active mineral admixtures mills. Portland cement size composition is defined by a screen № 008, oversize of not more than 15%. Finely ground “pure” clinker is characterized by a short setting time (3 to 5 min), and as such, is not suitable in pure state for any practical purposes.

Setting time of cement is controlled by adding gypsum during grinding in amounts from 1,5 to 3,5% of the weight of cement. Portland cement containing gypsum within the above range, satisfies the standard specifications, as its setting begins not earlier than 45 min and ends not later than 12h from the time of its mixing with water.

Portland cement may be manufactured with or without active mineral hydraulic admixtures (puzzolana: volcanic ashes, diatomites, opoka or granulated

blast-furnace slabs), which are added in amounts of up to 20% of the weight of cement, if to increase amount of admixtures that may be obtained **puzzolana Portland cement** or **slag Portland cement**.

The hydraulic admixtures play the following part. They consist chiefly of amorphous silica which interacts readily with $\text{Ca}(\text{OH})_2$ with the effect that the soluble calcium oxide hydrate, resulting from the hydration of C_3S , is bound chemically into a practically insoluble calcium hydrosilicate $\text{CaO} \cdot \text{SiO}_2 \cdot n\text{H}_2\text{O}$, thus enhancing the water resisting property cement stone.

The major properties of cement: strength and rate of strength gain; durability; resistance to various service conditions. They depend on the quality of clinker, its chemical and mineralogical compositions. Limestone consists chiefly of two oxides (CaO and CO_2) while clay is composed of various minerals containing basically three oxides (SiO_2 , Al_2O_3 and Fe_2O_3). Carbon dioxide CO_2 is removed by burning the raw mixture, the four remaining oxides CaO , SiO_2 , Al_2O_3 and Fe_2O_3 forming the clinker minerals whose relative amount in Portland cement is as follows (in %):

- tricalcium silicate $3\text{CaO} \cdot \text{SiO}_2$ (alite) – 45-65;
- dicalcium $2\text{CaO} \cdot \text{SiO}_2$ (belite) – 15-35;
- tricalcium aluminate $3\text{CaO} \cdot \text{Al}_2\text{O}_3$ (celite) – 4-14;
- tetracalcium aluminoferrite $4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$ – 10-20.

Mixing of Portland cement with water, results to formation of a sticky cement paste, which gradually thickens and becomes stone like. Hardening of Portland cement involves very complicated chemical and physical phenomena. When water is added, each of the minerals reacts with it to yield new crystal compounds, which give a strong artificial stone. Hardening of Portland cement is thus governed in the main by the hydration of silicates, aluminates, and aluminoferrites of calcium.

The rate of setting and the rate of hardening are of major importance in the hardening of Portland cement. Clinker minerals differ in rate of reaction with water. The fastest to react is C_3A , followed by C_4AF and C_3S , and the slowest, C_2S . The rate of hydration of the clinker minerals also governs the rate of their hardening: the faster mineral hydrates, the faster its strength grows.

The hardening of Portland cement involves changes in its volume. When the process takes place in the air, the cement stone may shrink due to evaporation of water. Shrinkage is particularly undesirable, as the artificial stone may then crack.

To prevent shrinkage deformations, the hardening of cement, in particular in its initial stages, should be carried out in a humid medium.

Hardened cement stone is a microscopic heterogeneous system composed of crystalline concretions and gel masses consisting of colloidal particles. Cement stone structure is made more inhomogeneous by grains of cement which have only partly reacted with water.

The difference in physical and mechanical properties of crystalline and gel-like matter is one of the causes why the mineralogical composition of clinker affects some of the essential structural properties of cement stone, such as deformation ability, resistance to freezing-and-thawing and to humidifying-and-drying cycles. This allows to control the properties of Portland cement by a rational choice of its mineralogical composition and thus to obtain cements satisfying the requirements of specific working conditions.

The structure of cement stone is greatly affected by its porosity, connected with the initial content of water in the mix. A satisfactory mix of cement with water is obtained by adding from 2 to 3 times the amount of water required to interact with cement.

Thus, the greater part of mixing water remains free and causes numerous fine pores in hardened stone. Therefore, whenever a solid structure of cement stone is desired, a minimum amount of water should be used. The effect of this is that the strength and frost resistance of cement stone are enhanced.

The structure of the cement stone, in particular the presence of pores or gel-like matter, predetermines its tendency to deform under the action of humidity. When humidified, it swells and when dried, shrinks. Alternating compressive and tensile stresses, caused by variations in humidity of the surrounding medium, loosen and weaken the cement stone structure. The extent of humidity-caused deformations depends on the ratio of gel-to-crystalline phases in the cement stone. The greater the part of the crystalline phase, the greater is the air-resistance of cement stone.

According to the State Standard, the strength of Portland cement is defined by its compressive and bending strengths. The grade of cement is found by measuring the bending strength of slab specimen, 40×40×160 mm in size, and by the compressive strength of halves of slab specimens made of a plastic mortar composed of 1 part of cement and 3 parts of sand (by weight) and tested after 28 days. During this period the specimens are held under moist conditions (moisture 95-98 %) at a temperature of $20\pm 2^{\circ}\text{C}$. The breaking strength of 28-day-old cement is called the activity of cement.

Specimens are prepared from pure quartz sand of specified size and chemical composition, in order to eliminate the effect of the quality of sand upon the strength of cement and to obtain comparable results.

When attributing a certain grade to Portland cement (300, 400, 500, 600), the compressive and bending strengths of 28-day-old cement should not be less than 30, 40, 50, 60 and 4.5; 5.5; 6.6; 6.6 MPa accordingly.

Portland cement gains strength not at a uniform rate. It rises to about 40-50% of the cement grade on the third day and to 60-70% on the seventh. Subsequently, the rise in strength of cement slows down even more, and cement attains its grade strength by the 28th day.

However, under favorable conditions, the hardening of Portland cement may go on for months and even years with the effect that the final strength is higher than the grade (28-day-old) strength.

The strength of cement stone and the rate of its hardening depend on the mineralogical composition of clinker, cement fineness, water content, ambient humidity and temperature and duration of ageing.

The strength gain of clinker minerals composing Portland cement shows a great variety of patterns. Tricalcium silicate (C_3S) is the fastest one to gain strength: after 7 days of hardening it attains about 70% of its 28-day-old strength, and then the strength gain of C_3S slows down considerably.

Hardening of dicalcium silicate follows an altogether different pattern. During the initial period of hardening, the C_2S strength gain is small and amounts to about 15% from to 28 days, but during the period that follows, dicalcium silicate hardens at a high rate. Therefore, whenever a high-strength concrete is required within a short period of time, use is made of cement with a high content of tricalcium silicate and, conversely, if a high strength is desired at a later date (as in hydraulic engineering constructions), cement with a high content of C_2S should be used. Tricalcium aluminate has a low strength by itself, but it greatly speeds up the hardening of cement stone during the initial period of time. This property of C_3A is used to produce quick-hardening Portland cement. In mineralogical composition, it is high in C_3A and C_3S (about 60 to 70%, including up to 10% of C_3A).

The finer is cement, the greater is its strength, and also the greater is its degree of hydration, the higher is the content of crystals mineral hydrates, and the greater is the strength of the cement stone. The mean size of Portland cement is about 40 μ m.

The cements may have a fineness defined by a total retained on sieve No 008 of not more than 15%.

The fineness of cement may also be described by the unit surface area (cm^2/g), i.e. by the total surface area of grains (cm^2) per 1g of cement. The unit surface area of cement is 2500 to 3000 cm^2/g .

In some cases, clinker is ground to a greater fineness to increase the activity and obtain a quick-hardening cement.

The hardening of cement stone and the growth of its strength may go on only in the presence of water, since hardening is first of all a hydration process.

Practical means of humidifying cement stone as it hardens are as follows: spraying of concrete with water; putting wet sawdust sand, bast mats on concrete structures and periodically spraying them with water; coating concrete with bitumen emulsion and other materials which form vapourtight films and prevent evaporation of water; and, finally, covering concrete with polyethylene film.

Strength gain of cement stone is greatly affected by ambient temperature. The rate of chemical reactions between clinker minerals and water and the rate of consolidation of hydration products greatly increase with temperature.

Hardening of cement stone may take place in practice within a wide range of temperatures: normal hardening in the open air at positive temperatures; steam curing in cells between 50 and 90°C; autoclaving between 170 and 200°C at steam pressures from 0,8 to 1,2 MPa.

The quickest increase in the strength of cement stone takes place in the process of steam curing under pressure in autoclaves, the concrete attaining its grade strength in 4-6 h.

When concrete is steam-cured at normal pressure, it hardens about twice as long as in autoclaves. Concretes subjected to heat and humidity curing at a temperature up to 90°C generally attain only 70 % of their grade strength in 12-15 h.

Portland cement stone does not harden at subzero temperatures since water turns to ice.

Cements tend to lose their activity even when stored under the most favourable conditions. After three months of storage the loss in activity may be as high as 20%, and after a year, 40%. Cements of greater fineness lose their activity at a faster rate, as air moisture causes their premature hydration.

After a prolonged storage, cement can be reactivated by a fresh grinding.

Cement stone may be subjected to the corrosive action of the environment: fresh and mineralized water, combined action of water and frost, alternative humidification and drying.

Corrosion of cement stone in water may be divided, by major characteristics, into three types.

The first type of failure results from dissolution and washing out of calcium hydroxide, resulting from the hydration of tricalcium silicate by fresh running water. The cement stone becomes porous and loses strength. The resistance of cement stone to attack by fresh water under pressure can be substantially enhanced by the introduction of hydraulic admixtures to the cement and raise its density.

Hydraulic admixtures bind Ca(OH)_2 into a poorly soluble compound – calcium hydrosilicate ($\text{CaO} \cdot \text{SiO}_2 \cdot n\text{H}_2\text{O}$).

The second type of corrosion is the failure of cement stone under the action of water carrying acid or sour salts that are capable of entering into exchange reaction with the cement stone constituents, the products being either highly soluble substances that are readily carried away by water filtering through the cement stone or precipitating as amorphous mass that possesses no binding properties.

The effect of these changes is greater reduction of strength. All types of cements have no resistance under the action of water carrying acid or sour salts.

Processes due to the action of sulphates belong to the third type of corrosion. Poorly soluble substances, contained in water, or products resulting from their interaction with the cement stone constituents precipitate in the of cement stone.

Their accumulation and crystallization bring about considerable tensile stresses in pore walls and may ultimately lead to the failure of cement stone.

Cements of a low tricalcium aluminate content are more resistant to attack by sulphates.

Combined action of water and frost leads to failure of cement stone. At subzero temperatures, water in cement stone pores turns to ice, which means an expansion of about 9% as compared to the volume of water. The ice exerts a pressure against pore walls and causes their failure.

Frost resistance of cement stone depends on the mineralogical composition of clinker, fineness of cement and the water-to-cement ratio.

A considerable amount of admixtures in cement adversely affects the frost resistance of cement stone because of high porosity and low frost resistance of the products resulting from the interaction of the admixtures with the cement stone constituents.

Among the clinker minerals, the less frost resistant is C_3A , and, therefore, its content in cement intended for frost-resistant cement stone should not exceed 5 to 7%.

A higher water-to-cement ratio lowers frost resistance of the cement stone because of its increased porosity.

Thus, the frost resistance of cement stone may be enhanced by the use of cements of low C_3A content and a minimum of active mineral admixtures and by preparing cement mixes of the lowest possible water-to-cement ratio, the mixed being thoroughly compacted during placing.

Varieties of Portland cement

Quick-hardening Portland cement has a more intensive – as compared to common grades – strength gain during the initial period of hardening. This is achieved by a finer grinding of cement and appropriate correction of its mineralogical composition. The $C_3A + C_3S$ sum should be total 60-65%.

According to the State Standard the bending and compressive strengths of quick-hardening Portland cement after 3 days, should not be less than 4 and 25 MPa, respectively, and after 28 days, its compressive strength must be at least 50 – 60 MPa. This kind of cement has a high heat release.

Sulphate-resistant Portland cement is manufactured from clinker a predetermined mineralogical composition. The content of C_3S in cement should not be higher than 50%, of C_2S , not more than 5%, and the $C_3S + C_4AF$ sum should total not more than 22%. This kind of cement is rather slow in hardening and has a low heat release during the initial period. Sulphate-resistant Portland cement is available in grade 400 (compressive strength 40 MPa). In other respects, it meets the same requirements as Portland cement.

White and coloured Portland cements are manufactured from raw materials having a minimum content of colouring oxides (iron, manganese, chromium).

The source materials are “pure” limestone or chalk and white kaolin clays, and the fuel is gas or fuel oil which causes no ash contamination of the clinker.

The main property of white cement is the degree of whiteness. White cements are available in grade 400. This type of cement has low frost resistance.

Coloured Portland cement is manufactured by combined grinding of white cement clinker with alkali-resistant mineral pigments: ochre (yellow), ultramarine (blue), chromium oxide (green), smoke (black).

White and coloured cements are used for finishing works, in the manufacture of facing tiles, stairs treads, window sill slabs, textured panel faces, artificial marble.

Portland cements with active mineral admixtures. This group of hydraulic binding materials comprises cements obtained by combined grinding of Portland cement clinker and an active mineral admixture. Depending on the kind of the initial binder constituent and that of the admixture, cements with active mineral admixtures are divided into pozzolana or slag Portland cements.

Active mineral (hydraulic) admixtures are finely ground natural or artificial substances which, when added to Portland cement and mixed with water are capable of interacting chemically under normal conditions with calcium oxide hydrate. The obtained stone has low solubility and high improving water-resisting properties.

Pozzolana Portland cement is obtained by combined fine grinding of clinker, a predetermined amount of gypsum (up to 3,5%) and an active mineral admixture (volcanic origin from 21 to 40% and sedimentary origin from 21 to 30%).

The setting time and the fineness of pozzolana cement are the same as for common Portland cement, although pozzolana Portland cements are characterized by a smaller strength gain during the initial period of hardening. Pozzolana cement is produced in grades 300 and 400.

There are two stages in the hardening of puzzolana Portland cement: first, hydration of Portland cement clinker minerals, second, interaction of an active mineral admixture with calcium oxide hydrate which is released during the hardening of clinker. At the same time, $\text{Ca}(\text{OH})_2$ is bound into a water-insoluble calcium hydrosilicate, therefore cement stone from puzzolana Portland cement acquires greater water-resisting property than cement stone from common Portland cement.

A relatively small amount of heat is released in the setting and hardening of puzzolana Portland cement, a fact which makes the cement suitable for large concrete constructions. Puzzolana Portland cement is not suitable for elements exposed to systematic moistening and freezing or drying conditions.

Cement stone from puzzolana Portland cement have lower water permeability than from common Portland cement because of the expansion of admixtures which make the cement stone denser.

Puzzolana cements are particularly suited for underwater and underground concrete and reinforced concrete constructions, particularly so in applications, where concretes are expected to be extra water-impermeable and water-resisting.

Slag Portland cement is a hydraulic binding material obtained by combined grinding of Portland cement clinker, granulated blast-furnace slag and gypsum. The part of granulated blast-furnace slag in Portland cements should not be less than 21% and not more than 60% of the weight of the finished product.

Hardening of slag Portland cement may be divided into processes, the primary one consisting of hydration and hardening of the clinker part of cement and the secondary one involving chemical interaction of hydrated products of the clinker part with granulated blast-furnace slags.

As compared to common Portland cement, slag Portland cement features a slower strength gain during the initial period of hardening, but its grade strength and subsequent gains are approximately the same. Strength gain of slag Portland cement falls off sharply and appropriate humidity favour the hardening of slag Portland cement to a greater extent than that of Portland cement. By compressive and bending strengths, slag Portland cement is divided into grades 300, 400 and 500.

Water resistance of cement stone from slag Portland cement is higher than that of common Portland cements because of the absence of free calcium oxide hydrate. Slag Portland cement stone has satisfactory frost and air resistances, but it is higher temperatures resistant (700°C) than stone from Portland cement (300°C).

Slag Portland cement is used for similar purposes as common Portland cement. But, owing to its higher water-resisting, lower water permeability, higher salt-resisting property; it should be preferred in hydraulic engineering in-

stallations and also in construction intended for service in moist media. Slag Portland cement is also used for production hot-resisting of concretes. This cement should not be used in constructions exposed to frequent freezing-and-thawing or moistening-and-drying conditions.

Cements with surfactants organic admixtures. This group of hydraulic binding materials comprises cements obtained by combined grinding of Portland cement clinker and surfactants organic admixtures of 0,06 to 1,0%. Depending on the kind of the admixture (hydrophilic and hydrophobic) cements are divided into plasticized and hydrophobic Portland cements.

Plasticized Portland cement differs from the common grades by the inclusion of plasticizing admixture which enhance mobility and if the water-to-cement ration is reduced, hardened cement stone highly frost resistant can be made. Plasticized Portland cement is available in two grades: 400 and 500.

The admixture molecules form water coats around cement grains and thus act as a lubricant which reduces the friction between the grains and so enhances the plasticity of the cement grout. Plasticized cements – whose strong points are better placeability and greater frost resistance – may be used along with cements of the common grades. They find particularly wide use in road, air-field and hydraulic engineering construction.

Hydrophobic Portland cement differs from common grades of concretes by the presence of hydrophobic surfactant admixtures.

Hydrophobic admixtures form thin (monomolecular) films on the surface of cement grains and thus decrease their wettability. This type of cement neither loses activity nor forms lumps under moist conditions. At the same time, when cement mix is being prepared, the absorption films are torn off the surface of cement grains and thus do not prevent normal hardening of cement.

Hydrophobic cement features greater water resistance, water impermeability and frost resistance of cement stone.

The weak points of hydrophobic cement are its small strength gain during the initial period because of the hydrophobic films on cement grains which prevent the interaction with water, but its 28-day strength is equal to that of common Portland cement. Hydrophobic Portland cement is available in two grades: 300 and 400.

Special varieties of cement

Aluminous cement is a quick-hardening hydraulic binding material obtained by fine grinding of a burned (at melting or caking at a temperature of about 1600°C) mixture of bauxites and limestone with a prevailing amount of

high action calcium aluminates in the product. When aluminous cement is mixed with water, the formation of plastic paste, its subsequent consolidation and hardening are similar to those of common Portland cement. Aluminous cement gel consolidates and crystallizes at a very high rate, the effect being rapid strength gain. After approximately 5 to 6 h, aluminous cement may attain 30% and over its grade strength value, and after a day of hardening, over 90% and at the end of 3 days, the grade strength.

Aluminous cement is a quick-hardening, but not a quick-setting binding material, it should begin to set not earlier than 30min and end not later than 12 h after mixing with water.

By compressive strength, aluminous cement is divided into three grades, 400, 500 and 600, after 3 days of hardening under normal condition. Most favourable for hardening of aluminous cement are moisture atmosphere and normal temperature ($20\pm 5^{\circ}\text{C}$). Strength gain slows down at temperatures above 25°C . The strength can even drop and cement stone can disintegrate as a result of recrystallization of new formation.

Therefore, no steam curing of aluminous cement items is allowed.

Aluminous cement hardens satisfactorily at temperatures below normal or close to zero, which is due to its high heat of hydration. Over a period of 1 to 3 days, aluminous cement releases from 1,5 to 2 times more heat than Portland cement.

Large heat release limits the use of aluminous cement in heavy constructions since the heating of concrete inside the body of a construction and its cooling on the outside cause tensile stresses in the outside layers and lead to cracks.

Artificial stones from aluminous cement are air-, water-, and frost-resistant and also show good service in fresh and sulphate waters, but disintegrate under the action of alkali water.

The use of aluminous cement is substantially limited by its cost (which is 3 to 4 times higher than that of Portland cement), although in physical and mechanical properties (hardening rate, resistance to attack by various media), it is superior to other cementing materials, including Portland cement. In practice, aluminous cement is used in urgent repair work (repair of dams, pipes, roads, bridges and urgent laying of foundations), where its specific properties find the most rational application.

Chemical stability of aluminous cement allows to use it for plugging up oil and gas wells, in the food industry plants, in pickling and dye works, for lining shaft pits and tunnels.

As compared to other binding materials, aluminous cement is resistant to the action of high temperatures (1200 to 1400°C and over), a property which makes it suitable for the manufacture of heat resistant concretes intended for lining thermal units.

The next group of binding materials encompasses cement that show a slight increase in volume in the course of hardening under moist conditions, or that do not shrink when hardened in the air.

Expanding cement is a quick-setting and quick-hardening hydraulic cementing material obtained by grinding or mixing finely ground aluminous cement, gypsum and high basicity calcium aluminate in a ball mill. Setting begins not earlier than 4 min and ends not later than 10 min after water is added. Setting may be retarded by the special admixtures. Compressive strength of specimens from cement paste should not be lower than: in 6 h – 7,5 MPa; in 3 days – 30 MPa; in 28 days – 50 MPa. After one day of hardening, the specimens should be fully impermeable to water applied under pressure of 0,6 MPa. Linear expansion after one day of hardening should not be less than 0,2 and not more than 1%.

Water impermeable expanding cement is used for repairing concrete and reinforced concrete constructions, for water-proofing tunnels and pit shafts, in underground and underwater constructions, for water-impermeable joints.

Gypsum-aluminous expanding cement is a quick-hardening hydraulic binding material obtained by combined fine grinding or mixing of high-alumina slag and natural dehydrate gypsum (30%).

Gypsum-aluminous cement is available in three grades, 300, 400 and 500. Setting begins not earlier than in 20 min and ends not later than in 4 h after mixing with water.

Specimens from gypsum-aluminous cement paste should be, after one day, impermeable to water applied at a pressure of 1 MPa.

Linear expansion of cement after one day of hardening should not be less than 0,15% and not more than 1,0%, its average value after 28 days being 0,1 to 0,3%.

Gypsum – aluminous cement is used for the manufacture of nonshrinking and expanding water – impermeable mortars and concretes, for caulking joints, for water – proofing underground mines.

3.6. Artificial Stone Products from Mineral Binding Materials

Mineral binding materials are used for manufacturing of mineral-body paints, building mortars, asbestos-cement items and concretes.

3.6.1. Mineral-Body Paints

Mineral body colours are mixtures of alkali and light-resistant pigments, fillers and non-organic vehicles with various additives, thinned with water to painting consistency.

By the kind of vehicle, mineral-body paints are available in lime water, silicate and cement types.

Lime water colours are composed of lime, pigment. These colours are used for painting of brick, concrete and plastered surfaces of interior premises.

Silicate colours are made from mixtures of finely dispersed chalk, talcum, white zinc, alkali-resistant pigment, and sodium or potassium soluble glass. Shop silicate colours are available of two kinds for finishing facades and interiors. Facade colours are used for painting facades and interiors of premises with normal and high atmospheric moisture; colours for interior finishing are used for coating concrete plaster and resin free wood fibre boards.

Shop cement colours are mixed with water prior to use. They are employed for exterior and interior coating of premises with high atmospheric moisture, for cellular concrete and for relief finishing.

Polymer-cement colours are prepared from cement, alkali- and light-resistant pigments with additions of synthetic resins, and are available in various colours and in summer and winter-job varieties. Summer-job colours are mixed with a water-dispersed polymer prior to use, their field of application is exterior and interior finishing of various surface quality.

Plant-fabricated winter-job polymer-cement colours are used for exterior finishing of building fronts and constructions.

Painting jobs call for a number of auxiliary materials, such as fillers and primers.

Fillers are finishing compounds intended for smoothing surfaces prior to painting. They are available in various compositions, depending on the kind of paint to be used (gypsum, cement, soluble glass).

In finishing jobs, primers (lime water, soluble glass) are employed for reducing the porosity of surfaces to be painted, to reduce the consumption of expensive paints and to provide stronger bonds between paint and the supporting surface.

3.6.2. Building Mortars, Its Classification and Properties

Building mortar is a mixture consisting of mineral binding material, fine aggregate (sand) and water. Mortars are classified by their bulk density, kind of binding material, application, and physical and mechanical properties.

By their bulk density in dry state, mortars fall into the following kinds:

- heavy mortars of a bulk density of 1500 kg/m^3 and over which are manufactured from heavy quartz or other sands;
- lightweight mortars of a bulk density less than 1500 kg/m^3 in which the aggregates are light porous sands from pumice, tuffs, slags, ceramsite and other fine aggregates.

By the kind of binding material, building mortars are subdivided into the following varieties:

- cement mortars prepared from Portland cement or its varieties;
- lime mortars, the binding material in which is an air-hardening or hydraulic-hardening lime;
- gypsum mortars prepared from gypsum binding materials, such as building gypsum, and anhydrite binding materials;
- composite mortars obtained from cement-lime and cement-clay binding materials.

The kind of a binding materials for a mortar is selected according to its intended application, requirements imposed upon it, hardening temperature, moisture conditions and expected working conditions of the building or installation.

By application building mortars are subdivided into:

- masonry mortars intended for brickwork and walls from large components;
- finishing mortars for architectural or ornamental parts, application of decorative layers on wall blocks and panels;
- special mortars with particular properties (acoustic, heat-insulating, waterproofing, X-ray shielding).

The basis for the general classification of mortars by their physical and mechanical properties are two majors characteristics – strength and frost resistance, which underlie the durability of mortars. By compressive strength, building mortars are subdivided into nine grades ranging from 4 to 300 Pa. There are nine frost resistance grades – from F10 to F300 – the figures indicating the number of freezing-and-thawing cycles the mortar can withstand.

The mortar composition is designated by the volume or weight of material in 1m^3 of mortar or by the relative amount of initial materials, the amount of binding material being taken as unity. For simple mortars, composed of one kind of binding material and containing no mineral admixtures (cement or lime mortars), the composition will be designated, say, i.e. one part (by weight or volume) of binding material and 6 parts of sand. Combined mortars composed of two binding materials (cement + lime) or containing mineral admixtures (lime + clay) are identified by three figures, say, 1 : 0,4 : 5 (cement : lime : sand or lime : clay : sand).

The fine aggregates for heavy mortars are natural quartz sand or sand obtained by crushing solid rocks; for lightweight mortars, pumice, tuff, shell, slag sands.

Chief properties of mortar mixes are mobility and water retention, and those of mortars are strength.

A mortar mix may have a consistency depending on its composition. The mobility of a mortar mix is determined by sinking a metal cone, weighing 300 g and, into the mix. The mobility of a mortar mix determines its placeability, i.e., the possibility of placing it in a thin and uniform layer that makes a strong bond with the surface of the bed.

Water retention is characterized by the ability of mortar not to stratify during transportation and to retain adequate humidity in a thin layer spread over a porous bed. A mortar mix of low water retention, and, when laid upon a porous bed (clay brick, concrete, wood) gives away its water to it. Mortar may lose so much water that the amount left may be insufficient for its hardening, with the effect that the required strength is not attained.

Mineral and organic admixtures are introduced into Portland cement mortars to enhance placeability. Clay or lime in the form of paste are effective mineral admixtures to cement mortars. They improve water retention and placeability of cement mortars and save cement. Used as non organic disperse admixtures are active mineral substances, such as diatomite, tripoli, ground slags. Surfactants organic admixtures when introduced in tenths and hundredths of 1% of the quantity of binding materials, improve plasticity of mortars and reduce consumption of binding materials, strength of hardened mortar depends on the activity of binding materials, the content of finely ground admixtures. And the cement-to-water ratio mortar strength is also governed by the consumption of cement and the quality of sand.

The strength of mortar is designated by its grade, which is equal to the compressive strength (P) of cubic specimens with a side measuring 70,7 mm and prepared from a working mortar mix on a water sucking bed after 28 days hardening at a temperature 15-25°C.

When mortars from slag Portland cement and puzzolane cement and puzzolana Portland cement are used, the rate of strength gain is lower at temperatures below 10°C

Building mortars of various uses

The composition of masonry mortars and the kind of binding material depend on the type of construction and its working conditions.

Building masonry mortars are available in four kinds: cement, cement-lime, cement-clay and lime mortars.

Portland cement and slag Portland cements are used for walls from panels and large concrete and brick blocks, for common masonry (from high-grade mortars) and also for masonry performed by the freezing method.

Cement-lime and cement-clay mortars are readily placeable, very strong and highly frost-resistant. These mortars are used for underground and above-ground parts of buildings.

Lime mortars have a high plasticity, good cohesiveness with other surfaces and shrink very little. They are sufficiently durable, but harden slowly. Lime mortars are used for constructions of lightly loaded above-ground parts of buildings.

Mobility of masonry mortars is a function of their application (vertical and horizontal joints) and kinds of wall materials: concrete blocks, brick, light-weight rock stones, rubble. Mobility and water retention of mortars are adjusted by the addition of non-organic or organic plasticizers.

Masonry for walls from regularly shaped stones is prepared from sand up to 5 mm in size.

Finishing mortars include common plasters and ornamental mortars. Plastering mortars are prepared on cements and cement-lime, lime, lime-gypsum and gypsum binding materials.

Plasters for exterior stone and monolithic concrete walls of buildings with relative air humidity up to 60% should be mixed for exterior wooden and gypsum surfaces in regions with a stable and dry climate, from lime-gypsum mortars. Socles, belt courses, cornices and other parts of walls exposed to repeated wetting should be plastered on the outside with cement and cement-lime mortars from Portland cements. Interior plasters for walls and floors of buildings with relative air humidity up to 60% should be made of lime, gypsum, lime-gypsum and cement-lime mortars.

The binding materials for preparing ornamental mortars are as follows:

- Portland cements (common, white and coloured) for finishing lamellar reinforced concrete panels and lightweight aggregate concrete panels;
- lime or Portland cement (common, white and coloured), for face finishing of lime –sand panels and for coloured plasters of facades;
- lime and gypsum for coloured plasters intended for interiors of buildings.

Aggregates for coloured ornamental mortars are washed quartz sand and sand obtained by crushing granite, marble, tuff and other white or coloured rock. Maximum size of sand should not exceed 2,5 mm.

The finishing coat can be given a decorative luster by adding of mica or of crushed glass to the mortar. Plasters are coloured by alkali-resistant and artificial pigments.

Depending on the field of application, the finishing mortars are subdivided into mortars for exterior and interior plastering. Plastering mortars are composed according to their intended use and working conditions of buildings and installations. Plastering mortars should have an adequate degree of mobility, good cohesiveness with the bed and small volumetric variations in the process of hardening, so as not to cause cracking.

Mobility of plastering mortars and the largest grain size of sand for each plasters coat (the rendering and finishing coats) are different.

Plaster mortars should have a high mobility. Mobility, water retention and resistance to atmospheric exposure of ornamental coloured mortars can be improved by introducing hydrophobic or plasticizing admixtures.

Mortars for filling joints between parts of prefabricated reinforced concrete constructions, injection mortars, floor mortars, floor mortars, damp-proofing mortars, plugging mortars, sound-absorbing and X-ray shielding mortars are known as special mortars.

Mortars for filling joints between prefabricated reinforced concrete components (mounting mortars) are prepared with Portland cement and quartz sand.

Mortars that are intended to support the design load should be of a grade equal to that of concrete constructions being joined, whereas non-load-bearing mortars should have a grade not less than 100. Whenever joints include reinforcement or insertion pieces, mortars should carry no admixtures liable to cause corrosion of metal.

Cement-sand and cement paste injection mortars intended for filling grooves inside prestressed constructions must comply with stringent specifications as to strength (grade not less than 300), water retention and frost resistance.

Floor mortars are subdivided into the following varieties: cement-sand, metal-cement, cement-sawdust and polymer-cement. Cement-sand mortars for grouting floors should have adequate strength and good mobility.

Cement-sand mortars for floors from paving blocks, clinker bricks, concrete slabs, mosaic and ceramic tiles and cast iron perforated plates and xylolite tiles should have adequate strength and viscosity.

Metal-cement mortars are manufactured from degreased steel shavings 1-3 mm in size, cement and water in grades 300-500 and higher and low mobility.

Cement-sawdust mixes consist of Portland cement or anhydrite binding material, sand and fine sawdust. These mortars are intended as bed courses for floors.

In recent years there is evidence of an even increasing trend in building practice to make floors from polymer-cement mortars that are prepared by mixing cement with an aqueous suspension of a polymer (synthetic latex). Floors on such mortars have adequate strength, corrosion resistance, hygienic properties and high resistance to wear.

Damp-proofing mortars are prepared on cements of higher grades (400 and over) and quartz sand or sand from crushed solid rock. Damp-proofing courses are built with sulphate-resisting Portland cement, as binding materials. Cracks and caverns in concrete can be filled and concrete or stone masonry can be plastered by guniting or by conventional methods with cement mortars carrying admixtures of sodium aluminate, polymers and bitumen emulsions.

Waterproof seams and joints are made from damp-proofing mortars prepared with waterproof expanding cement.

Packing mortars are subdivided into cement-sand, cement-sand-loam and cement-loam varieties and are used to pack oil wells. Properties required of them are high homogeneity, water resistance and mobility; predetermined setting time, adequate water yield under pressure and ability to form solid waterproof plugs in cracks and voids of rocks; resistance to subsoil water pressure and to attack by aggressive media. Suitable binding materials for packing mortars are Portland cement; for aggressive water – slag Portland cement, puzzolana and sulphate-resisting Portland cements and when water pressure is expected – packing Portland cement.

Sound-absorbing mortars have a bulk density of 600-1200 kg/m³ and are used as sound-absorbing plaster to reduce the noise level. The binding materials involved are Portland cement, slag Portland cement, lime, gypsum or their mixtures are single-size fraction sands (3 to 5 mm) from lightweight porous materials, such as pumice, perlite, cinders, ceramsite, etc. The quantity of binding materials and the grain composition of aggregate in sound-absorbing mortars should ensure an open porosity of the mortar.

X-ray shielding mortars for plastering walls and ceilings of X-ray cabinets are heavy mortars of a bulk density over 2200 kg/m³. The binding materials are Portland cement and slag Portland cement, and the aggregates, barite and other heavy rock in the form of sand (up to 1,25 mm in size) and dust. Admixtures (hydrogen, lithium, cadmium) are added to X-ray shielding mortars to enhance their protective properties.

Building mortars are prepared in two kinds: as ready to use mortar mixes of adequate mobility and as dry mortar mixtures requiring water and, sometimes, introduction of special admixtures.

At present, commercial mortars are being prepared in a centralized manner at specialized plants and are transported to construction sites as dry mixes or finished mortars of specified consistency, grade and quality.

3.6.3. Asbestos-Cement Items

Asbestos cement is an artificial stone material obtained by hardening a mix of cement, water and asbestos, the latter reinforcing the cement stone in the asbestos cement and providing high strength of items in tension and bending.

Asbestos cement has a high mechanical strength in binding, small bulk density, low heat conductivity, high resistance to attack by mineralized aqueous solutions, high water tightness and frost resistance.

Its shortcomings are low strength when saturated by water, brittleness and warping as an effect of humidity fluctuations.

The principal raw materials for the manufacture of asbestos-cement items are chrysotile-asbestos and Portland cement.

Asbestos-cement items are manufactured from the mixture of asbestos in the amount of 10 and 20%, and the part of Portland cement being 80 to 90%.

The binding material in asbestos-cement is Portland cement which must hydrate rapidly but set relatively slowly and not earlier than 1,5 h from the time it is mixed with water. After the items are manufactured, the strength gain should be sufficiently rapid to allow the semi-product to turn into a finished item.

Asbestos minerals are fibrous in structure and split into fine fibres under mechanical force. Diameter of chrysotile-asbestos fibres lies between 0,00001 and 0,00003 mm, but in practice chrysotile-asbestos can be luffed to fibres of a mean diameter of 0,02 mm, and, therefore, such a fibre is actually a bunch of numerous elementary fibres. Their strength drops to 600-800 MPa, which corresponds to the strength of high-quality steel wire.

Asbestos has a good adsorption capacity. When mixed with Portland cement and wetted by water, it adsorbs, i.e., retains firmly on its surface, the asbestos fibres, and, therefore, asbestos-cement can be considered a finely reinforced cement stone. Chrysotile-asbestos is incombustible; however it melts at a temperature of about 1550°C.

Asbestos has low heat and electric conductivity, high resistance to alkali and poor resistance to acids.

The quality of asbestos is critically affected by the length of fibres, and, therefore, this characteristic serves as a basis for classifying asbestos into eight grades.

Water used for production of asbestos-cement items should be free from clay impurities, organic substances and mineral salts. The optimum temperature of water is 20-25°C.

Wall tiles and sheets may be tinted by coloured cements or mineral alkali-resistant pigments which possess high colouring ability, high light stability and resistance to atmospheric action and cement hydration products.

Sheets intended for facing walls and panels of sanitary units and kitchens are coated with water-impervious enamels and varnishes manufactured from polymers.

Asbestos-cement items are currently manufactured by two methods: from an asbestos-cement suspension, the wet method (sheets, pipes); from an asbestos-cement-sand mass, the semi-dry method (sheets, slabs).

The most extensively used is the wet method.

The flowsheet of manufacturing asbestos-cement items comprises the following main stages:

- composing a mixture from a number of grades and marks of asbestos;
- fluffing the asbestos mixture;
- preparing the asbestos-cement (asbestos-cement-sand) mass;
- forming the asbestos-cement items.

The pipes and sheets obtained by wet method are moulded in sheet-forming and pipe-forming machines. In order to obtain greater mechanical strength and density (semi-dry method) facing sheets and roof tiles items are compacted in hydraulic presses at pressure up to 40 MPa.

Asbestos-cement items from Portland cement harden in two stages. First, they are pre-hardened in pit or tunnel bath-type steam curing chambers at temperatures between 50 and 60°C for 12 to 16 h. After final forming, the sheets are transferred to a heated storage area, where the second stage of hardening takes place over a period of not less than 7 days. Formed asbestos-cement items from sandy Portland cement are charged into autoclaves for steam curing at temperatures of 172-174 °C and a working pressure up to 0,8 MPa. After curing to required strength, items are dressed.

By application, asbestos-cement items fall into roof and wall items, pipes and special items.

Sheet asbestos-cement materials are extensively used in building practice. Corrugated sheets of periodic profile in coloured or non-coloured varieties are available in length of 2000 and 2500 mm, widths of 1154 and 1150 mm and 1093 mm and thicknesses of 6 to 8 mm. These sheets are used for exterior walls in various types of buildings.

Asbestos-cement corrugated sheets of standard profile are intended for garretless and heat-insulated roofs and walls of industrial and farm buildings and installations.

Facing asbestos-cement slabs with ornamental polymer coat (sizes of 150×150×4 mm) are used to line walls of shops, cafeterias, underground railway stations, street underground crossing, public premises, and walls of bathrooms.

Standard asbestos-cement wall panels consist of three layers in which the facing asbestos-cement sheets are secured to a wooden carcass by aluminium cramps and the interior asbestos-cement sheathing from grey sheets, by screws with countersunk heads; the heat insulating materials are glass wool slabs.

Asbestos-cement pipes are available in pressure, pressureless and ventilation types. Pressure-type pipes are used for water supply lines, for district heating and for oil and gas pipelines.

Pressureless asbestos cement pipes are used for exterior pressureless sewers, drainage headers, land reclamation systems and telephone cable ducts.

Asbestos-cement troughs rectangular in cross section are intended as ventilation ducts for industrial auxiliary premises and welfare blocks, industrial, apartment and public buildings.

Special asbestos-cement items are large-size textured sheets intended for arched roofs, water towers, grain driers.

3.6.4. Concretes. Classification of Concretes

Concrete is an artificial stone resulting from hardening of a rationally chosen mixture of binding material, water and aggregate (sand and crushed stone or gravel). The mixture of these materials before it hardens is called concrete mix.

Particles of sand and crushed stone form a stone carcass in concrete. Cement paste resulting from the interaction of concrete mix with water coats the grains of sand and crushed stone, fills the voids between them, lubricates the aggregate and imparts mobility to the concrete mix. When cement paste hardens, it binds the aggregate into an artificial stone or concrete.

Concrete combined with steel reinforcement is called reinforced concrete.

Concretes are classified according to the following main characteristics: bulk density, type of binding material and aggregates, structure, strength, frost resistance, waterproof, application.

By application, concretes are divided into the following kinds:

- constructional, for concrete and reinforced concrete supporting elements of buildings and installations (columns, beams, plates):
- special, such as acid- and heat-resistant concretes, for biological shielding, extra-heavy concretes for protection from nuclear radiation, hydraulic engineering for dams, sluices and etc.

By their bulk density concretes are divided into superheavy concretes with a bulk density over 2600 kg/m^3 , heavy concretes with a bulk density of 2000 to 2600 kg/m^3 , lightweight concretes with a bulk density between 200 and 2000 kg/m^3 .

By the maximum size of aggregate, concretes are subdivided into fine-grained varieties with aggregates of up to 10 mm in size and coarse grained varieties, the maximum size of aggregates ranging from 10 to 150 mm.

According to the kind of aggregates concretes may be concretes with dense, porous or special aggregates.

According to the kind of binding material, concretes are available in the following varieties:

- cement concretes manufactured from hydraulic binding materials, such as Portland cement and its varieties;

- lime-sand (silicate) concretes, from lime binders in combination with silicate compound;
- gypsum concretes, from gypsum-anhydride binding materials;
- concrete from organic binding materials.

Strength and frost resistance are major characteristics of the quality of concretes. Heavy concretes have compressive strength between 10 and 60 MPa, lightweight ones, between 2,5 and 30 MPa. By frost resistance, concretes are subdivided into grades: heavy concretes, from F 50 to F 300; lightweight concretes, from F 10 to F 200.

Heavy concrete is manufactured from cement and common dense aggregates, and light weight concrete, from cement and natural or artificial porous aggregates.

3.6.4.1. *Materials for Concretes*

Heavy concrete for the manufacture of foundations, columns, beams, bridge spans and other supporting elements and constructions of industrial and residential buildings and engineering installations should acquire a predetermined strength after a certain period of hardening, whereas the concrete mix should be readily placeable.

Concrete is used for production of bearing reinforced concrete structures on the workplace (monolithic concrete); for manufacture of large-size constructions (slabs, blocks) in a plant and also for small-pieces roofing and finishing materials (pic. 25-28).

When used in locations exposed to weather conditions, concrete should have a high density and adequate frost and corrosion resistances.

Lightweight concretes of low heat conductivity on porous aggregates serve to manufacture panels for walls and floors of heated buildings.

Depending on application and working conditions, the ingredients of concrete must satisfy various requirements.

Concretes are prepared from Portland cement, plasticized Portland cement, slag Portland cement, etc. Lime-sand concretes are obtained by mixing lime and quartz sand subsequently hardening moulded items in autoclaves at pressures between 0,8 and 1,2 MPa and temperatures from 170 to 200°C.

The type of cement is chosen according to the demands placed upon concrete (strength, frost resistance, chemical stability, water impermeability, etc.).

Water for concrete mixtures and spraying should be free from harmful impurities which may hinder the normal hardening process of concrete. Classed with these impurities are acids, sulphates, grease, vegetable oil, sugar, etc. No swamp or drainage water or water contaminated by harmful impurities should be used.

Sea and other types of water, containing mineral salt, may be used if their amount is limited to 2%.

The various additions are intended to improve the properties of concretes and mortars. By their kind and application, the additions may be classed as follows: early-strength admixtures; surfactants; foam and gas forming agents; combined and special-purpose additions.

The common early-strength admixtures that speed up the hardening of concrete particularly during the initial stages.

Surfactants (0,05 to 0,2% of cement mass) are a particular group of organic substances whose introduction into concrete (mortar) mixes substantially improves latter's placeability. At the same time, the surfactants lower the water-cement ratio and, accordingly, the consumption of cement with no adverse effect upon the strength of materials and items.

Surfactants used in cements, mortars, and concretes may be classed, on the basis of the effect they exert upon cement systems, into three groups: hydrophilic, hydrophobic and air-entraining.

Hydrophilic admixtures prevent for a specified time sticking of cement particles to one another as a binder is mixed with water. Because of this a specified placeability of such a mix is attained at a lesser amount of mixed water than is the case for an admixture-free mix.

Hydrophobic admixtures substantially enhance, as a rule, the resistance to unmixing and the cohesiveness of a concrete (mortar) mix at rest. In addition, these admixtures protect cements against a rapid loss of activity during transportation or storage.

Air-entraining additives enable obtaining concrete (mortar) mixes with some additional amount of air that enhance the placeability of the mix and frost resistance of concrete.

Foam- and gas-forming agents are used for manufacturing lightweight cellular concretes. They are distinguished by a high porosity (up to 80-90%) with uniformly distributed pores, up to 3 mm in size.

Combined additives, as plasticizer, hardening accelerator with inhibitor, contribute to an economy of cement.

Special additives make it possible to obtain water-proof mortars and concretes and to control hardening time in freezing weather.

Petty aggregate – sand is a loose assembly of particles 0,14 to 5 mm in size, formed as a result of natural disintegration of massive rocks (natural sands). Along with natural sands, use is made of artificial ones obtained by crushing of granulating metallurgical slags or fuel cinders, or of specially prepared materials, such as ceramsite, agloporite. Of natural sands, mostly used for concrete are the quartz sands.

The quality of concrete is greatly affected by the granulometric composition of sand and the quantities of various dust, slime, clay and organic impurities, whose content is found by elutriation, and their amount in sands should not exceed respectively 3%. Most harmful in sand are clay impurities which coat individual sand particles and prevent their bonding with the cement stone, thus diminishing the strength of concrete. Clayey and dust impurities in sands increase the water-requirement of concrete mixes and lower their strength and frost resistance.

The size (granulometric) composition of sand is of prime importance for the manufacture of high-quality concrete.

Sand intended for concrete should be composed of particles of different sizes (from 0,14 to 5 mm) so as to minimize the volume of voids in it; the less the volume of voids in sand, the less the amount of cement required to obtain dense concrete. The size composition of sand is determined by screening the latter through a standard set of sieves with sizes of openings (from top to bottom) of 10;5; 2,5; 1,25; 0,63; 0,312; 0,14 mm. The amount of particles in the 5 to 10 mm range should not exceed 5% by mass.

On the basis of its size sand is classified into coarse, medium, fine and extra-fine varieties.

Coarse aggregate for heavy concrete is usually composed of gravel or crushed rock.

Gravel is a conglomeration of fragments from 5 to 70 mm in size, formed by natural disintegration of rock. Gravel particles have a well-rounded shape and a smooth surface. By the size of particles, gravel is subdivided into the following fractions: 5-10; 10-20; 20-40; 40-70 mm. Gravel frequently occurs together with sand. When the amount of sand in gravel amounts to 25 to 40%, the material is called sand-gravel.

Crushed stone is obtained by crushing massive rocks, gravel to particles measuring 5 to 70 mm. Best crushed stone is that approximating cubes and tetrahedrons form. Because of a ragged surface, crushed stone provides a better bond with cement than gravel, but a concrete mix prepared with the use of crushed stone is less mobile.

It is more economical to prepare concrete with the use of coarse gravel and crushed stone since its smaller surface area requires less cement for obtaining strong concrete. The admissible size of particles depends on the constructions to be made of concrete. Easy placing of a concrete mix requires the gravel or crushed stone to be not coarser than $\frac{1}{4}$ of the minimum size of the construction cross section and not larger than the least distance between the reinforcement bars. In slabs, where it is easier to place a concrete mix, larger particles

may be used, their size not exceeding $\frac{1}{2}$ of the slab thickness. Gravel and crushed stone larger than 70 mm are used in concretes for massive hydraulic engineering installations.

A good composition contains particles of various sizes because this minimizes the volume of voids.

The strength of particles of gravel and crushed stone used in the construction of industrial and civil buildings installations should be at least 1,5 times higher than that of concretes of grades below 300, and at least twice as high as than of concretes of grade 300 and over.

Gravel and crushed stone intended for concretes exposed to the action of water and low temperatures should have a certain frost resistance, in terms of which they are classed into grades F 15, 25, 50, 100, 150, 200 and 300. Frost resistance is found by direct freezing. Gravel or crushed stone are considered frost-resistant if being water-saturated, they withstand more than 15 cycles of alternate freezing at -17°C and thawing, the loss in mass after the tests amounting to not more than 10%.

The aggregates for lightweight concretes are natural and artificial loose porous materials with a bulk density of not more than 1200 kg/m^3 for particles in sizes up to 5 mm (sand) and not more than 1000 kg/m^3 for particles ranging in size from 5 to 40 mm (crushed stone, gravel).

Natural porous aggregates are obtained by crushing lightweight rock, such as pumice, volcanic cinder and tuff, porous limestone, shell limestone, limestone tufas.

Artificial porous aggregates are obtained from industrial waste (slag) or through thermal processing of raw silicate materials which are screened or crushed and screened.

Granulated slag is a porous fine material obtained by rapid cooling of molten metallurgical slags.

Slag pumice (thermosite) is obtained in lumps of cellular structure by expanding molten slag, as it solidifies, with the aid of water cell or a combination of both.

The strength of slag pumice ranges from 0,4 to 2,0 MPa depending on its bulk mass (400 to 800 kg/m^3).

Agloporite is an artificial porous aggregate ranging in size from 5 to 20 mm, bulk mass from 400 to 700 kg/m^3 and compressive strength from 0,4 to 1,5 MPa. The raw materials for the manufacture of agloporite are clay and waste of coal mining. Agloporite crushed stone is manufactured by sintering raw mixture, then it crushed and screened.

Classed with the specially prepared aggregates are ceramsite gravel and sand, which are rounded materials, obtained by burning clay. A porous structure is achieved by expanding a clayey substance heated to a pyroplastic state by

gases evolving from it during heating. Ceramsite gravel is manufactured in strengths of 0,6 to 6 MPa, and bulk mass of 150 to 800 kg/m³. Ceramsite sand is obtained by crushing and screening ceramsite gravel, or as an independent size fraction directly in burning.

Expanded pearlite is manufactured in the form of stone and sand by short-time-burning of volcanic water-containing glass rocks. Pearlite stone and sand for concretes have a bulk mass of 150 to 450 kg/m³ whereas the pearlite sand used for heat insulating fillings is produced in bulk masses of 50 to 100 kg/m².

3.6.4.2. *Properties of Concrete Mixes and Concretes*

The concrete should acquire its design strength at a given time and possess such qualities as are required of the construction being manufactured from it (water and frost resistance, density, etc.). In addition, the concrete mix should have an adequate mobility.

In buildings and installations, concrete may be subjected to various stresses, such as compression, tension, bending, spalling. Concrete is best in compression, this being its basic mechanical property.

Concrete grade is determined by the compressive strength of a cubic specimen with sides measuring 15 cm, made from a working concrete mix, after 28 days of hardening under normal conditions.

Compressive strength of concrete depends on the cement activity, water-to-cement ratio, quality of aggregate, degree of compaction of the concrete mix and hardening conditions, the first two of these being the determining factors. Cements of higher activity produce stronger concretes, but concrete of constant activity may show different strengths depending of the quantity of water in the mix.

In order to obtain a concrete mix of adequate placeability the water-to-cement ratio is usually maintained between 0,4 and 0,7, whereas the amount of water necessary for the chemical interaction between cement and water is not more than 20% of the mass of cement.

Excess water, which has not reacted with cement, evaporates and forms pores in concrete, thus lowering the density and, therefore, the strength of concrete. It follows then that the strength of concrete may be increased by bringing down the water-to-cement ratio.

The strength of aggregate does not affect the strength of concrete greatly as long as it is strength higher than the design grade of concrete. Use the aggregates whose strength is lower than that of the desired grade of concrete may substantially lower the latter's strength or lead to a higher consumption of cement.

Surface roughness of aggregates also affects the strength of concretes.

In contrast to gravel, crushed stone has a developed rough surface which provides better cohesion with cement stone, whereas concrete, prepared from crushed stone, has greater strength than concrete mixed with gravel, provided all other conditions are the same.

Along with the above factors (activity and quality of cement, water-to-cement ratio and quality of aggregates), the strength of cement is greatly affected by the compaction of the concrete mix, the duration and conditions of hardening.

Cement concretes continually gains in strength at favourable temperature and humidity. For the first 7 to 14 days the strength of concrete grows rapidly, and then it slows down by the 28th day and gradually stops increasing; in a moist warm environment the strength of concrete may grow for many years.

The variation of concrete strength with time roughly follows the logarithmic law; on this basis, the strength of concrete may be roughly calculated for different periods of hardening by means of the empiric formula

$$R_n = R_{28} \frac{\log n}{\log 28},$$

where R_n – strength of concrete after n days, Pa;

R_{28} – strength of concrete after 28 days, Pa;

n – time hardening, days.

This formula can be used for a rough estimation of the strength of concrete from Portland cements after 3 days. The actual strength of concrete in structure is found by testing specimens prepared from working concrete mixes.

Concrete strength gain is greatly affected by the surrounding medium. The conditions generally accepted as normal for the hardening of concrete are as follows: relative humidity of air, 90 to 100%; temperature, $20 \pm 2^\circ\text{C}$. High air humidity is necessary to minimize the evaporation of water foam concrete which may cause the hardening process to stop.

The higher the temperature, the greater the rate of hardening of concrete, and vice versa. Thus, in 10 to 14th of hardening in a steam saturated atmosphere (steam curing) at a temperature between 80 and 90°C , concrete may attain from 60 to 70% of its 28-day grade strength.

Hardening of concrete is accelerated by such admixtures as calcium and sodium chloride. This has great practical significance for concreting in the cold season, because the accelerants also allow to mix concretes capable of hardening at subzero temperatures.

Even with high-quality materials, concrete can be made, strong and durable only if the mix is thoroughly compacted when placed into a construction. The moulding capacity of a concrete mix is determined by two factors – mobility and plasticity. Plasticity is an indicator of internal cohesion of a concrete mix, its ability to be moulded and to acquire a prescribed shape without breaks and stratification.

The mobility of a concrete mix is evaluated by its ability to flow under its own weight or under vibration. This characteristic is found by means of a conical mould which is filled with concrete mix; the latter is compacted and the mould is then taken off. The resultant cone of concrete mix slumps under its own weight. The slump of the cone (cm) is a measure of the mobility of the concrete mix, which allows the following classification of concrete mixes: cast mix, slump over 20cm; mobile mix slump from 10 to 20 cm; poorly mobile mix, slump from 1 to 9 cm, stiff and extra stiff, no slump, less 1 cm.

Stiffness of concrete mixes is determined with the aid of a technical viscosimeter.

The ability of a concrete mix to flow under vibration is the stiffness. The time of vibration in seconds is the measure of the concrete mix stiffness.

Cast and mobile mixes have a stiffness of 0 s; poorly mobile 4 and less s; stiff, 5 to 40s; and extra stiff over 40 s.

Concrete mix mobility is affected by such factors as type of cement, content of water and cement paste size of aggregate, shape of aggregate ingredients, sand content.

Concrete mixes of the same composition but from different cements have different mobilities because of different water requirements. Concrete mixes from Portland cements with hydraulic admixtures have a lower mobility than mixes from Portland cement, when the amount of water for preparing the mix is the same.

The greater the water content (cement consumption being the same), the greater the mobility of the concrete mix but the concrete strength is lower. The greater the amount of cement paste in a concrete mix, the greater the latter's mobility, the post-hardening strength remaining practically unchanged. This is due to the fact that as the content of the cement paste increases it not only fills the voids between the aggregate particles and coats them, but also pushes them apart; the effect is that cement paste forms thick interlayers which reduce friction between the particles and thus increase the mix mobility.

When coarser aggregate is used, the total surface area of particles is smaller, and, therefore, for the amount of cement paste, the interlayers separating the aggregate particles are thicker, a fact which enhances concrete mix mo-

bility. The increase in the amount of sand above the optimum value, which is based on practical data, reduces the concrete mix mobility because of a greater surface area of the aggregate.

Particle shape affects the mix mobility: the total surface area of the aggregate and the friction are less when the particles are rounded and smooth than when they are sharp-edged and rough. Therefore, a concrete mix from gravel and rounded sand is more mobile than that from crushed stone and rock sand.

The mobility of a concrete mix should be as low as possible, but consistent with adequate placeability. When choosing the mobility of a concrete mix, the size and the character of the construction, the simplicity should be taken into account.

The aim of designing concrete composition is to establish such a demand of materials per 1m^3 of concrete mix which allows the most economical preparation of a readily placeable concrete, as well as its frost and water resistance and special properties, whenever these are required.

A concrete mix composition is expressed as a mass ratio (seldom, as a volume ratio which is less accurate) of cement, sand and crushed stone (or gravel) with the indication of the water-to-cement ratio, the quantity of cement being taken as unity.

Therefore, in its general form the composition of a concrete mix, is given as a ratio of cement : sand : crushed stone = 1 : x : y with $W/C = z$ (for instance 1 : 2,4 : 4,5 with $W/C = 0,45$).

Distinction is made between two compositions of concrete; nominal (laboratory) composition, for dry materials, and industrial (field) composition, for materials of natural humidity.

The quality of source materials (cement, water, sand and crushed stone or gravel) should be evaluated in accordance with the state standard specifications before the composition of a concrete mix is calculated.

The initial data for calculating a concrete mix are as follows: given grade of concrete (R_{con}); mobility or stiffness of concrete mix; parameters of ingredients, such as activity (R_{cem}) and bulk density of cement, density and bulk density of sand or gravel and voidage of crushed stone or gravel.

The procedure for calculating the composition of concrete is as follows:

- determination of the water-to-cement ratio ensuring the manufacture of concrete of prescribed strength;
- determination of water consumption;
- determination of the required consumption of cement, crushed stone (or gravel) and sand;

- the mobility of a concrete mix is checked;
- preparation of specimens for strength tests and testing after ageing;
- when the indexes (mobility and strength) deviates from the design value, the correction of the composition of the concrete mix is carried out;
- re-calculation of the nominal composition in terms of industrial composition.

Should the concrete mix prove to be less mobile than required, the amounts of cement and water are increased, the cement-to-water ratio remaining unchanged. If the mobility is higher than required, sand and aggregate are added by small portions in a predetermined ratio until proper mobility is reached. When changing the contents of sand and crushed stone (gravel), their humidity must be taken into account.

When concrete is mixed, smaller particles of ingredients occupy the space between the larger fragments; sand fills the voids between crushed stone or gravel, and cement paste, between sand particles. The volume of a concrete mix (V_{con}) is therefore, always less than the sum of the bulk volumes of dry loose ingredients. This calls for the introduction of concrete yield factor β which is the ratio of the volume of the concrete mix V_{con} in compacted state to the sum of bulk volumes of dry loose ingredients ($V_c, V_s, V_{cs(g)}$)

$$\beta = \frac{V_{con}}{V_c + V_s + V_{cs(g)}}.$$

Factor β is used for calculating the amount of materials for preparing a batch in a concrete mixer of a given capacity V or for performing a given construction work.

$$C_v = \frac{\beta V}{1000} C, \quad W_v = \frac{\beta V}{1000} W,$$

$$S_v = \frac{\beta V}{1000} S, \quad CS_v = \frac{\beta V}{1000} CS,$$

where C_v, W_v, S_v, CS_v – amounts of cement, water, sand and crushed stone (or gravel), respectively, required to make a batch in a concrete mixer, kg;

β – concrete yield factor;

C, W, S, CS – consumption of cement, water, sand and crushed stone (or gravel), respectively, kg/m^3 of concrete mix.

Basic considerations for choosing the composition of lightweight concrete from given materials are the concrete's lowest possible cost consistent with good placeability and adequate strength, as well as specified bulk density for the lowest consumption of cement.

3.6.4.3. *Manufacture of reinforced concrete constructions and items.*

Reinforced concrete is a building material that combines advantageously the load-bearing abilities of concrete and of steel, which differ greatly in mechanical properties. Similar to other rock materials concrete operates well in compression, but is brittle and poor in tension.

Tensile strength of concrete is equal to 1/15 – 1/10th of compression strength, so that it is bad practice to use it in units subjected to tensile stresses, since the units must be made very heavy. But steel, which is very strong in tension, is capable of resisting tensile forces that may arise in reinforced concrete units.

Reinforced-concrete items are most advantageous in units subject to bending, when both tensile and compressive stresses take place. Steel resists the composite unit successfully withstands the bending loads. In this manner the load-resisting abilities of steel and of concrete are combined in a single material – reinforced concrete.

The successful combination in reinforced concrete of two materials with greatly differing properties is based on the following factors:

- strong bond of concrete with steel reinforcement so that the two materials offer a combined resistance to loads;
- almost equal thermal expansion coefficients of steel and concrete, this making reinforced concrete a monolithic tem;
- concrete is not only non-aggressive with respect to steel, but even protects it against corrosion.

Depending on the reinforcing technique and the state of reinforcement, distinction is made between common and prestressed reinforced concrete. In the same class with reinforced concrete are products whose strength is enhanced by placing steel bars, wire meshes or carcasses into concrete. However, this reinforcing method fails to prevent cracks in the stretched parts of concrete, since the latter's stretchability is poor (1-2 mm per 1 m), whereas the tensile strength of steel is 5-6 times greater than that of concrete. Cracks adversely affect the working properties of reinforced concrete units; camber increases, moisture and gases penetrate into the cracks and there is a risk of reinforcement corrosion.

Cracks in reinforced concrete can be prevented by compressing concrete at points subject to tensile stresses. Prestressed concrete cracks only if the tensile

stresses exceed the prestress value. Concrete is compressed by pretensioning (stretching) the reinforcement.

There are two kinds of tensioning: pretensioning, or tensioning the reinforcement before the concrete hardens, and post-tensioning, or tensioning the concrete after it acquires a specified strength. If the reinforcement is prestressed before the concrete is placed, the reinforcement is laid inside the form and fastened after being tensioned. Once the mix is placed and concrete has hardened, the reinforcement contracts as soon as it is relieved of extraneous tension, and in so doing drags along the surrounding concrete, compressing the unit throughout its body.

If the reinforcement is to be tensioned after the concrete hardens, it is inserted inside a channel. Once the concrete has hardened, the reinforcement is tensioned and secured at its ends by anchoring arrangements. The mix, poured inside the channel, bonds the reinforcement to the concrete, and so provides monolithic reinforced concrete.

Prestressing the reinforcement not only prevents cracking in stretched concrete, but also reduces the weight of reinforced concrete, constructions, enhances their rigidity, increases durability and brings down the consumption of steel. This is why construction engineers devote so much attention to the development of prestressed reinforced concrete structures. Reinforced-concrete items and constructions should be received at the construction site and on plant.

The manufacture of reinforced concrete items and constructions generally involves the following sequence of operations: preparation of concrete mix; reinforcement; forming; hardening of concrete to provide necessary strength by a specified time.

In the present-day industry of prefabricated reinforced concrete, process operations are organized and carried out by means of corresponding equipment in accordance with the three flowsheets below.

1. Items are cast in stationary forms; all process operations, from preparation of forms to stripping of hardened items are performed at a single station (trusses; sanitary closets are made from a monolithic reinforced concrete three-dimensional shell cast in special boxes).

2. Items are made in mobile forms, process operations being performed at specialized stations. The form and the item it contains are transferred from station to station as the separate operations are performed (wall panels single-, two- and three-layers).

3. Continuous casting. The unit in which the items are manufactured by the continuous casting technique is the vibro-rolling mill (partition panels are made of all kinds of concretes).

The main operations in the process of preparing concrete mixes are proportioning and mixing of ingredients. According to existing norm, the proportioning tolerances are $\pm 1\%$ by mass for cement, water and admixtures and $\pm 2\%$ for aggregate.

Concrete mixes are prepared in batch and continuous concrete mixers.

The duration of stirring of a concrete mix depends on the latter's mobility and the capacity of the concrete mixer. The less is the mobility of a concrete mix and the larger is the mixer's working capacity; the greater is the optimum time of mixing.

During transportation of the concrete mix to the site of placement, its homogeneity and mobility should be preserved. On the way, concrete mixes may thicken because of hydration of cement, adsorption of water by the aggregate and evaporation; in no case, however, should a mix be placed in a construction unless its mobility is in compliance with the design value.

When considering the haulage of concrete, account should be taken of the distance, the time of transportation, the mobility of the mix and the economics involved. At ready mix plants, concrete mixes are handled by concrete distributors, belt conveyors. Plastic mixes may be conveyed through great distances via pipes with aid of pneumatic devices. Concrete mixes are carried to concreting sites in transit or in agitating trucks where the mix is made ready roughly 5 minutes before it is delivered.

Each batch of concrete is accompanied by a certificate from the ready-mix plant with the name and address of the plant, number and date of issue of the certificate, amount of mix (m^3), consumption of cement per cubic metre of concrete mix, size content of crushed stone or gravel, mobility, stiffness and grade of concrete mix, and results of checks on control samples of concrete for strength. To prevent an early thickening of mixes, especially in hot weather during long transits, the mixes are doped with surfactants which slow down the structure formation of mixes in the initial 2 to 4 h.

The placing of a concrete mix and compaction inside a form is one of the most labour- and power-consuming operations. One of the most widely used techniques for compacting concrete mixes is vibration.

The type of vibrator should suit the kind, shape and size of the construction being concreted. Large open concrete surfaces (floors, slabs, roads) should be compacted with the aid of external vibrators, which transmit vibrations to the concrete mix via a metallic platform (float) which carries the vibrators.

Internal vibrators are used for compacting concrete mixes in massive constructions of great thickness.

Vibrating plates are much in use at prefabricated concrete plants.

The methods of compacting mixes are closely related to the properties of mixes, in particular, to mobility. Thus, harsh non-flowing mixes require vigorous compaction and the items made from them should be intensely vibrated or vibrated with weighting (or applying a load). Harsh mixes may also be compacted by tamping, pressing and rolling. Mobile mixes are readily and effectively compacted by vibration.

Mixes intended for casting are so mobile that they are capable of compacting under their own mass. To enhance compaction, they are sometimes vibrated for a short period of time.

Thus, all the known methods of concrete compaction fall into the following categories: vibrating, pressing, rolling, tamping and casting. The most effective, both from the engineering and economical standpoints and the most extensively used method is vibrating. It is successfully employed in combination with other mechanical compaction techniques, such as tamping (vibro-tamping), pressing (vibro-pressing), rolling (vibro-rolling). A variety of mechanical compaction is centrifuging which is applied to moulding hollow tubular items (pipes, power transmission line poles).

A concrete mix is compacted by centrifuging due to centrifugal forces arising during rotation. Concrete is compacted in centrifuges which are tubular forms rotated at 600 to 1000 rpm. The concrete mix of adequate mobility is forced against the inside of the form and thus compacted by the force arising from its rotation. Centrifuging also removes from 20 to 30% of water a fact greatly contributing to the manufacture of high-density, of high strength (40 to 60 MPa) and durability concrete.

Pipes, power transmission line poles, lighting fixture post are cast by centrifuging.

3.6.4.4. *Hardening and Curing of Concrete*

Curing of concrete involves means that provide normal hardening of concrete mixes and prevent damage to green concrete structures. Curing should be organized immediately after concrete is placed and compacted. First, it is imperative to protect the surface against drying.

An efficient means for curing freshly placed concrete in road construction is to coat its surface by film-forming substances, such as bitumen emulsions, latex, synthetic rubber, etc. Along with this, horizontal surfaces of products are covered with sand or sawdust after concrete has set, the materials being wetted at regular intervals. The time of moistening, is a function of atmospheric conditions: in hot weather, it is up to two weeks; in cold weather, several days.

In cold seasons, concrete should be protected against excessive cooling, which slows down hardening, and the more so against freezing.

Hardening is the final operation in the manufacture of reinforced concrete constructions and items.

Depending on the environmental temperature, there are three different hardening schedules: normal treatment at a temperature from 15 to 20°C, thermal treatment at a temperature below 100°C and normal pressure; autoclave treatment involving steam curing at elevated steam pressure, and temperature higher than 100°C.

Irrespective of the hardening schedule, the relative humidity of the medium should be close to 100%, otherwise the concrete will dry up and slow down or even stop gaining strength since hardening of concrete is basically hydration of cement, i.e., the interaction of cement with water.

Normal hardening conditions may be attained naturally, with no consumption of heat whatsoever. Under natural conditions, concrete gain the necessary shipping strength (70% of the grade strength) during 7-10 days. Already there are concretes which gain 40-50% of grade strength in one day under normal conditions. This is achieved by using high-grade quick-hardening cements, stiff concrete mixes, intensive vibration with additional loading, hardening accelerators, vibroactivating and preheating concrete mixes prior to casting.

When concrete is placed in freezing weather, it should be protected against freezing until it acquires 50% of its design strength. Normal hardening of concrete at subzero temperatures may be acquired by two methods: by utilizing the internal heat of concrete or by supplying an additional amount of heat from outside.

To reduce the time of hardening it is necessary to use such cements as Portland cements of grades 400, 500 and aluminous cements, to lower the water-to-cement ratio, to intensify the compaction of concrete mixes and to introduce hardening accelerants, such as calcium chloride, etc.

A reserve of internal heat is provided by heating concrete mix ingredients (water, sand and crushed stone or gravel) in a manner to bring the concrete mix temperature on discharge from a concrete mixer to not higher than 30°C. The reason for this is that a mix tends to thicken rapidly and lose its workability when temperature level is exceeded. Mixing water may be heated to 80°C, and the aggregate, to 40°C. In addition, heat that is released by chemical reactions between cement and water (heat released in the hydration of cement) counteracts the cooling of the constructions.

In order to retain the heat during a predetermined time, concrete constructions are covered with heat insulating materials (sawdust, slag, pressboard, flax waste), as soon as the concrete mix is placed, the thickness of the coat is deter-

mined on the basis of thermal considerations, and the technique is called “thermos”. It is applied to heavy constructions with a surface modulus (which is the ratio of the cooling surface of concrete F to its volume V) not greater than 6.

In thin and sometimes in massive freshly placed constructions, the concrete mix is heated from the outside by steam or electric current (electric heating). This technique allows to achieve in one or two days a strength gain of 60 to 70% of the grade strength (after 28 days of hardening).

Concrete can be heated by alternating current which is supplied through electrodes of two types: surface electrodes (in the form of steel plates placed on the surface) and internal electrodes (steel bars laid horizontally or stuck in vertically). In reinforced concrete construction the reinforcement serves as one of the electrodes.

As current flows through concrete, it releases heat with the effect that concrete hardens rapidly. However, concrete should not be heated to a temperature higher than 60°C; otherwise a local overdrying may occur.

Thermal-and-moist curing under normal pressure. There are several methods for thermal-and-most curing of reinforced concrete items under normal pressure: steam curing in chambers; electric heating; contact heating. Among the great variety of techniques, chamber steam curing is still the most advantageous method. This method is implemented in batch-type and continuous chambers. In the latter freshly cast items are continuously charged on cars at the end of the chambers tunnel and hardened products are discharged at the other end. Hardening involves curing in preheating, isothermal (of constant peak steam curing temperature) and cooling zones. This type of steam curing equipment is currently found at conveyor-type plants only.

Among the batch-type chambers, mostly used are pit chambers which are about 2,0 m deep, rising 0,5 to 0,7 m above floor level. Chamber dimension correspond to the size of items. The most advantageous size of the chamber is one corresponding to the size of a single item.

Items are charged into the chamber by a crane in several layers.

Steam curing conditions are characterized by the duration of temperature rise, holding at peak temperature, cooling time and the peak temperature during isothermal curing. Hardening schedules are drawn with due regard of the cement and its kind, properties of concrete mix (stiff or mobile), kind of concrete (heavy or lightweight), size of item (thin-walled or massive). An average schedule may be exemplified by the following parameters: heating at a rate of 25-35°C/h, cooling at a rate of 30-40°C/h, and isothermal holding for 6-8 h at a peak temperature of 80-90°C. Thus, the total steam curing time for items from common Port-

land cement averages 12 to 15 h. In the first place, hardening conditions are governed by the kind of cement. Quick-hardening cements reduce the duration of isothermal holding to half the time. Moreover, optimum heating temperature of these cements is 70 to 80°C, which also brings down the heating and cooling time substantially. As a result, the overall thermal treatment time for items from quick-hardening Portland cements is brought down to 6-8 h, the strength of cured items being 70-80% of its grade value.

Slow-hardening cements (puzzolana and slab Portland cements) require more time for isothermal holding (up to 10-14 h) and a higher isothermal heating temperature (up to 95-100°C). Thus, the overall steam curing time for concrete items from puzzolana or slab Portland cement is 16 to 20 h.

Use of stiff concrete mixes of low initial water content reduces the duration of steam curing by 15 to 20%.

Items from lightweight concrete heat up slowly because of their high heat-insulating properties, and so require prolonged thermal curing schedules.

Autoclaving. The rate of most chemical reactions, including the interaction of cement with water, on which the hardening of concrete is based, increases with the rise in temperature. Moreover, hardening of concrete requires a moist atmosphere. These two factors are successfully combined in the curing of items by high pressure steam. Temperature of saturated steam rises with pressure. At normal pressure, the temperature of saturates steam (100% relative humidity) cannot be higher than 100°C. Should this temperature be exceeded, the relative humidity will drop to below 100%, and concrete items start drying.

Items are generally autoclaved at a pressure between 0,8-1,2 MPa, corresponding steam temperature approximating 170-200°C, the items then gaining grade strength within 8 to 10 h, which provides a sizeable economic effect.

A major or virtue of concrete autoclaving is that sand, which is inert at normal temperature, becomes active at higher temperatures and interacts vigorously with lime to yield concrete of a strength of 20 MPa and over. This allows a wide use of concrete for the manufacturing of strong, water-resisting and durable items by autoclaving. An autoclave is a steel cylinder 2m in diameter; up to 20 m long, tightly sealed at the ends by heads.

However, autoclaves are much used in the manufacture of items from lime-sand items: brick, large-size items from dense lime-sand concrete (heavy concrete) and items of cellular structure feature low bulk density and heat conductivity (lightweight concrete).

Cellular lime-sand items are available in two kinds – foam and gas lime-sand.

3.6.4.5. *Properties of Concrete*

Density and impermeability of concrete

High-density concrete is obtained by a rational choice of aggregate (of minimum voidage), use of concrete mixes of low water-to-cement ratio, intensive compaction, introduction of plasticizing and hydrophobic surfactant admixtures.

It should be borne in mind, however, that there is no such thing as absolutely dense concrete. Its porosity is due to the evaporation of water which has not interacted chemically with cement as it hardens, to incomplete removal of air bubbles during compaction of the concrete mix, etc. Therefore, concrete is a material permeable to gases.

To make concrete constructions gas-impermeable, their interior surfaces are coated with gas-impermeable films, such as plastic.

An adequately thick construction from dense concrete with a fine pore structure is practically watertight. Water impermeability of concrete is characterized by the highest pressure of water which concrete is capable of resisting without letting water through. According to the impermeability to water, concretes fall into grades: W2, W4, ... , W20 that correspond to pressures of 0.2, 0.4, ... , 2.0 MPa, respectively.

Thinner constructions can be made perfectly watertight by using hydrophobic cement. Another method consists in applying a coat of waterproof plaster by pneumatic techniques (quniting).

A dense concrete can be made impermeable not only to water, but also to viscous oil products, such as fuel oil and heavy oil. Light medium oil fractions, e.g., gasoline and kerosene penetrate concrete with greater ease than water. In order to protect concrete and reinforced concrete installations intended for storage of heavy oil products, their surfaces are coated with water glass; to protect them against penetration of light and fluid oil products (gasoline, kerosene, ect.), their surfaces are covered by special gasoline-proof membranes, special coats (plastic films) or by building concrete which is impervious to the above fluids.

Frost resistance is one of the major requirements upon a concrete for hydraulic engineering structures, road surfaces, bridge piers, etc. Frost resistance of concrete is characterized by the maximum number of freezing-and-thawing cycles that 28-days specimens are capable of withstanding without losing more than 5% of their strength and more than 3% of their mass.

The State Standard for heavy concretes, including hydraulic engineering concretes, specifies a few grades in terms of frost resistance: F15, F25, ..., F100. The grade of concrete is chosen by its frost resistance according to the climatic conditions (i.e., the number of fluctuations of the level of water that washes the concrete or the number of freezing-and-thawing cycles during the winter season).

Generally, frost-resistant concretes are of high density. Production of such concretes has been discussed previously. Aggregates play an important part in the frost resistance of concrete. The grade of aggregate in terms of its frost resistance should not be lower than that of concrete.

Deformation properties of concrete

In the process of hardening, concretes undergo volumetric changes. Hardening of concrete in the air (with the exception of concrete from non-shrinking and expanding cements) is accompanied by a decrease in its volume, i.e., by shrinkage.

When concrete hardens in water, its volume increases during the initial period of hardening; under air-setting conditions, concretes shrink. Concretes from fluid mixes (with high cement consumption and high water-to-cement ratio) shrink considerably. Shrinkage is maximum during the initial period of hardening, its value being 60 to 70% of the shrinkage after a month of hardening. This is due to the fact that cement paste loses water at a high rate owing to the evaporation and absorption of water by cement as it hydrates. Dehydrated particles draw close together, and the cement stone shrinks.

Volumetric changes in massive concrete constructions during the initial period of hardening are due to expansion caused by the heat released during exothermic reactions between cement and water, which may raise the temperature inside heavy concrete constructions up to 50°C. Volumetric changes of concrete may cause considerable deformation and even cracking of constructions. To prevent such things, special expansion joints are provided in massive concrete constructions, and use is made of cements with a low heat release.

The shrinkage of Portland cement concrete depends on the mineralogical composition and fineness of cement, the shrinkage increasing with fineness.

Corrosion of concrete and means of protection

Practice has shown that concrete constructions may fail under physical and chemical action of liquids and gases. Concrete is corroded mainly through disintegration of the cement stone (while the aggregate may have been chosen adequately resistant). Physical and chemical processes taking place in the corrosion of cement have already been discussed in the chapter 3.5.2.

Corrosion of concrete is due to the penetration of an aggressive substance into the body of concrete; the corrosion is particularly intensive when such substances continuously filtrate through cracks and pores in concrete. Therefore, the principal means of protection against corrosion is to make concrete as dense as possible and do design correctly the constructional components, so as to ensure uniform deformation of concrete in the process of hardening (free from cracks).

Corrosion of concrete may be prevented by using cements containing substances that chemically bind the lime that is given off in the hydrolysis of tricalcium silicate, and which carry active mineral admixtures and small amounts of tricalcium aluminate. Classed with this type of cements are Portland cements with hydraulic admixtures, slag Portland cement, aluminous cement, sulphate pores in the surface layers of concrete. It is a current practice to impregnate concrete with cement mortar and soluble glass (a water solution of sodium silicate or potassium silicate). Concrete can be protected against corrodents by surface coats, (facing with solid impermeable ceramic tiles or stones laid with the use of acid-resistant cement); facing with waterproof bituminous materials.

High-temperature resistance. Concrete is a fire-resistant mineral material as it is capable of withstanding the action of high temperatures during fires. Fire resistance of concrete allows to use it for building chimney stacks of industrial furnaces and their foundations. Fire resistance of concrete depends not only on the kind of cement but also on the nature of aggregates. If the aggregates are composed of crystalline quartz rock, concrete may crack at about 600°C because of a considerable increase in the volume of quartz.

When designing concrete constructions that are continuously exposed to high temperatures, it should be remembered that the strength of concrete from Portland cement drops by 25% at temperatures between 150 and 250°C. It should also be pointed out that if concrete is heated above 500°C and then wetted, it will disintegrate.

Special heat-resisting concrete is used in constructions exposed to the action of high temperatures (above 250°C) for long periods of time; slag Portland cement is resistant to the action of 700°C, aluminous cement – from 1200 to 1400°C.

3.6.4.6. *Varieties of Heavy Concrete*

Heavy concrete (for building and special construction) is manufactured from cement and common dense aggregates.

By application special heavy concretes are divided into the following kinds: hydraulic engineering concrete, acid-resistant concrete, refractory concrete, coloured concretes, and road concrete.

Hydraulic engineering concrete is a variety of heavy concrete that is characterized by high water resistance, water impermeability, frost resistance, low heat release and an adequate resistance of chemical attack in aggressive media. Hydraulic engineering concrete is used for installations or parts of constructions periodically or continuously washed by water.

The classification of hydraulic engineering concrete takes into account the zones where concrete is used:

- underwater concrete, permanently located in water;
- concrete in the zone of fluctuating water level;
- concrete located above the fluctuating water level.

Underwater concrete, as well as that for fluctuating water level service and that exposed to the action of subsoil water should be resistant to corrosion by water of a given composition.

By compressive strength, hydraulic engineering concrete is determined at the age of 28 and 180 days.

The quality of hydraulic engineering concrete is favourably affected by active mineral admixtures to Portland cement which interact with calcium oxide hydrate and consolidate concrete, thus improving its water-resisting property and reducing heat release.

The water requirement of a concrete mix and the consumption of cement can be reduced, and the density and frost resistance of hydraulic engineering concrete enhanced by the use of surfactants.

Natural aggregates (sand and gravel) for hydraulic engineering concrete should satisfy the more stringent specifications than common concretes. Granulometric composition of aggregates should provide minimum voids and the greatest possible amount of large particles, so as to lower the consumption of cement and, therefore, reduce the heat release and the tendency to deformation in the process of hardening of concrete.

As it hardens, concrete should be given thorough care; it should be given thorough care; it should be supplied with adequate humidity and maintained at a constant temperature to avoid volumetric deformations of constructions.

Acid-resistant concrete is obtained from acid-resistant cement, which consists of an aqueous solution of sodium silicate (soluble glass), an acid-resistant aggregate in powder form (finer than 0.15mm) and an additive (hardening accelerant-sodium fluosilicate Na_2SiF_6) and also the aggregates (quartz sand, crushed stone from andesite, diabase and other acid-resistant materials).

Acid-resistant concrete should be hardened in a warm air-dry atmosphere (in constant to common concrete).

Acid-resistant concrete features solid cohesion with steel reinforcement, resistance to attack by sulphuric, hydrochloric, nitric and other acids (except hydrofluoric acid), a 3-day and 28-day compressive strength 12 and 20 MPa, respectively.

Acid-resistant concrete disintegrates gradually when acted upon by water and weak acids; concrete withstands well the action of concentrated acid, but decays rapidly when attacked by alkali liquors.

Acid-resistant concrete is used for various constructions and for lining floor and wall in the chemical industry.

Refractory concrete is capable of retaining (within specified limits) its physical and mechanical properties under prolonged exposure to high temperatures. By the kind of binding material, heat-resistant concretes face into the following categories:

- concretes from Portland cement (to 300°C);
- concretes from slag Portland cement (to 700°C);
- concretes from water glass (to 1000°C);
- concretes from high-alumina cement (to 1400°C).

The aggregates for refractory concrete are sand and crushed stone from chromite (to 1400°C), chamotte, fire-clay, blast-furnace slag, basalt, diabase (to 1000°C). This variety of concrete is used for building stacks and foundations for blast furnaces, open hearth and other types of industrial furnaces.

Coloured concretes are obtained by introducing alkali- and light-resistant pigments into the mix in amounts ranging from 8 to 10% of the weight of cement (ochre, mummy, minimum and others) or by using coloured cements. Sometimes recourse is made to aggregates possessing the required colour, e.g. tuffs, red quartzites, marble and other coloured rocks.

Coloured concretes are used for ornamental purposes in construction buildings and installations, underground pedestrian crossings, separating lines on traffic lanes, park lanes and also for the manufacture of items for public welfare (pic. 27,28).

Road concrete. Road concrete is subdivided according to its application into concrete for single-layer roads, for surface courses of two-layer concrete roads, for bed courses of two-layer roads and super-highways.

Service conditions of road concrete are very severe. It is exposed to repeated wetting and drying, freezing and thawing and wear by vehicle wheels, and, therefore, it must satisfy stringent requirements as regards strength, wear and frost resistances, as well as resistance to atmospheric erosion.

The grade of concrete by strength depends on its application.

A major strength characteristic of road cement and concrete is the tensile strength in bending.

Surface courses are made durable not only by proper manufacturing procedures, but also by the use of high-quality materials.

Road concrete is prepared from Portland cement and its varieties, such as plasticized and hydrophobic Portland cements.

Hardening accelerants, particularly effective in freezing weather, are admixtures of calcium chloride and sodium chloride in amounts up to 3% for non-reinforced, and 2% for reinforced surface courses and also sodium nitrite and potassium carbonate.

Concrete for radiation shielding. The use of atomic energy for peaceful purposes has necessitated means for protecting the personnel against the radiation hazard caused by nuclear reactors, atomic power stations, plants for manufacturing and processing isotopes, etc.

The degree of protection is determined by the thickness of the shield and its bulk density of fillers. The material that possesses both properties required for a radiation protection is concrete.

Aggregates used for shielding concretes are heavy materials, such as barite, magnetite, limonite and metal scrap, e.g., cast-iron shot, reinforcement and rolling mill waste, metal shavings, etc. The bulk density of protective super-heavy concretes depends on the kind of aggregate.

Binding materials for preparing superheavy, shielding concrete are Portland cement, slag Portland and aluminous cements.

3.6.4.7. *Lightweight Concretes*

Concretes of bulk density less than 2000 kg/m^3 are referred to a group of lightweight concretes of high porosity.

By the method of achieving artificial porosity, concretes fall into the varieties below:

- lightweight concretes from lightweight porous aggregate;
- large-pored (sand-free) concretes from single-size fraction solid or porous coarse aggregate containing no sand;
- cellular concretes with artificial cells which play the part of aggregate particles.

Concretes are variety of cellular concretes only with porous big aggregates (porosity of concretes are 7-25%).

By application, lightweight concretes are classified as follows:

- heat insulating concretes whose chief purpose is to enhance thermal resistance of exterior walls; their bulk densities are less than 600 kg/m^3 ; and coefficients of heat conductivity, not higher than $0,17 \text{ W/m}^\circ\text{C}$;
- structural concretes intended to carry large loads in buildings and installations; their bulk density, is $1400\text{-}2000 \text{ kg/m}^3$ strength grade not less than 15 MPa and frost resistance, not less than F25.
- structural and heat insulating concretes which combine the properties of both kinds of lightweight concretes; their bulk density is 600 to 1400 kg/m^3 ; coefficient of heat conductivity, not higher than $0,6 \text{ W/m}^\circ\text{C}$ strength grade, not less than 3,5 MPa.

Lightweight concretes from porous aggregates differ in principle from the common heavy concretes due to the specific properties of porous aggregates.

The aggregates have lower bulk densities than the solid ones, considerably smaller strengths, frequently below that of concrete, and highly developed and rough surfaces. These properties of lightweight aggregates govern those of lightweight concrete mixes and concretes.

Water requirements and water content of concrete mixes change sharply with the type of aggregate.

Optimum amount of water for preparing lightweight concretes depends chiefly on the water requirements of the aggregate and of the binding material (fineness and composition), mix compaction and concrete composition.

Water requirement of an aggregate depends on its granulometric composition and porosity, and commonly it increases with the total surface area and the porosity of its particles.

The fact that water is sucked from cement paster or mortar by the aggregates during preparation and placing of the concrete mix accounts for the latter's relatively rapid thickening, which causes stiffness and poor placeability. This specific property is enhanced also by the rough and highly developed surface of the porous aggregate. To improve mix mobility, greater amount of water should be added to it as compared to common (heavy) concretes.

Bulk density and strength of lightweight concrete depend chiefly on the bulk density and grain composition of the aggregate, the consumption of binding material and water and also on the method of mix compacting. The quality of the porous aggregate may serve as a rough indication of the concrete strength to be expected.

A special property of lightweight concretes is that their strength depends not only on the quality of cement, but also on its quantity, the strength and bulk density of concrete rising with cement consumption. This is due to the fact that the greater the quantity of the cement paste, the better the compactness of lightweight concretes and the higher the content of cement stone with is the strongest and the heaviest ingredients.

It is good practice to use highly active binding materials whenever the bulk density of concrete is to be reduced and its strength retained.

Heat insulating properties of lightweight concrete are function of the porosity and the nature of pores. In lightweight concrete, heat is transmitted through the solid carcass and the air filling the pores. Therefore, the bigger is the volume of pores, the better are its heat insulating properties.

Owing to porosity, lightweight concretes are less frost-resistant than the heavy ones, but are still suitable for exterior walls and other structures of buildings and installations.

Frost resistance of lightweight concretes can be enhanced by the use of artificial porous aggregates, processing low water absorption (e.g., ceramsite) and by increasing the porosity of cement stone. Frost resistance of lightweight concretes can also be improved by hydrophobic admixtures.

Versatility of lightweight concretes makes them suitable for various structural components of buildings and installations.

Thus, lightweight concretes of low heat conductivity on porous aggregates serve to manufacture panels for walls and floors of heated buildings.

Cellular concretes

Cellular concretes are a variety of lightweight concretes with uniformly distributed pores (up to 85% of the total volume of the concrete); they are obtained through hardening of a pre-expanded (by a pore-forming agent) mixture of binder, (cement or lime) water and siliceous component. These concretes do not have big aggregates.

By the kind of binder, cellular concretes are divided into the following groups: gas and foam concretes based on Portland cement or a cement-lime binder; gas-lime silicate and foam-lime-silicate concretes based on a mixture of quicklime and quartz sand; gas-slag and foam-slag concretes obtained from a mixture of lime and fine blast-furnace granulated slag or entrained cinder.

The cellular structure in the concretes is formed by means of foam-and gas-forming agent. The foam-forming agents are some varieties of surfactants substance that favour the generation of stable foam.

Widely used as gas forming agent is aluminium powder, which reacts with on aqueous solution of calcium hydroxide to give of hydrogen. The evolving hydrogen swells the mix which then hardens, while retaining a porous structure.

In Portland cement concretes, calcium hydroxide is formed as a result of the hydration reaction of tricalcium silicate, in lime-silicate concretes as a result of the hydration reaction of quicklime.

By hardening conditions, cellular concretes are divided into steam cured (gas and foam concretes) and autoclaved classes (gas-lime silicate and foam-lime-silicate concretes).

By application, cellular concretes are divided into heat insulating ones of a bulk density in dry state of up to 500 kg/m^3 and compressive strength grades of up to 25; structural-and-heat-insulating ones, of a bulk density of 500 to 900 kg/m^3 and compressive grades 25 to 75; and finally, structural cellular concretes, of a bulk density of 900 to 1200 kg/m^3 and compressive grades 75 to 200.

Cellular concretes being very porous feature a low bulk density and, accordingly, a relatively low strength. In the ideal case, the structure of a cellular concrete is composed of closed cells 0.4 to 1,5 mm across. The coefficient of heat conductivity of cellular concretes range from 0,07 to $0,25 \text{ W/m}^\circ\text{C}$.

The frost resistance grades for concretes are as follows: F10, 25, 35, 50, 100 and 200. A high frost resistance and a low coefficient of heat conductivity of cellular concretes depend to their structural particularities, or to numerous closed pores filled with air or gas. Blocks from cellular concretes are applied in heated buildings.

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И ИЗДЕЛИЯ**

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