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THEME № 1

CEMENT BINDERS

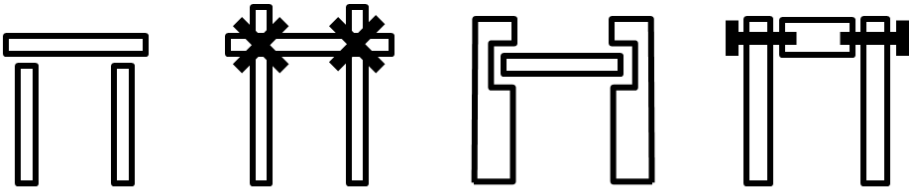
Summary

History of building construction. Chemical basis of cement binders. Technological scheme of cement production.

Theory

Our course is related with history and main concepts of mechanical equipment for building materials. But at first it is important to understand the nature of building materials.

From ancient times different objects made of rock formation became the most reliable place for living. We know them as caves. But mountains were not everywhere. So people try to imitate caves. They use different materials such as: wood, soil (ground), skin and animal bones. The elements of these buildings were connected to each other by different methods. By gravity, ropes, tenons, nails.

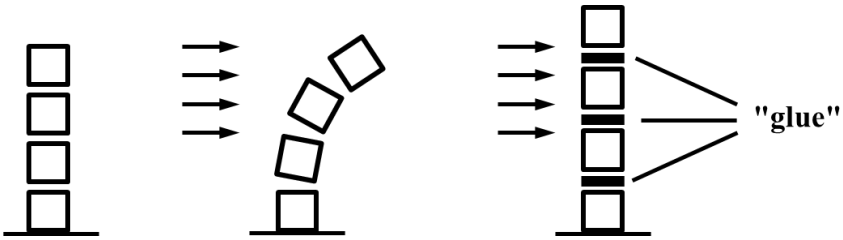


gravity **ropes** **tenons** **nails**

But these buildings did not have such hardness (endurance) as stone made one.

Stones were obtained in mountains and transported to building place. But it was very difficult to connect stones to each other.

The simple way was to put one stone on the top of previous. But for rather high (tall) buildings it is not enough for endurance.



Because of that the most famous ancient stone buildings have a pyramid form.

The reliable connection was needed.

The first attempts were to use clay. But it becomes wet during the connection with water. And after burning the clay loosed the endurance.

The first more reliable binders were discovered in the 3rd millennium BC. These binders were based on lime and gypsum.

$$\underset{\text{lim e}}{CaO} + H_2O \rightarrow \underset{\text{slaked lim e}}{Ca(OH)_2}$$

$$\underset{\text{half - water gypsum}}{2CaSO_4 \cdot 0{,}5H_2O} + 1{,}5H_2O \rightarrow \underset{\text{two - water gypsum}}{2CaSO_4 \cdot 2H_2O}$$

Much later people started to add burned and crushed clay to lime binder. It happened in Italy near the place called Pozzallo. Results became better.

But only in twenties of nineteen century a modern method of cement production was founded practically at same time in England and Russia. The Englishman Joseph Aspind and Russian building constructor Egor Cheliev offered to blend clay and chalk and then burned and crushed them. After that the ready powder (called clinker) connected with water and became the concrete or artificial stone.

$$\begin{matrix}\text{Clay}\\ \text{Chalk}\end{matrix} \xrightarrow{\text{blend}+\text{heating}} \text{Clin ker} \xrightarrow{\text{crush}+\text{grinding}} \text{Cement} \xrightarrow{\text{water}} \text{Concrete}$$

Let's look at some chemical reactions of this process.

Clay and chalk have this structure.

$$\begin{matrix}\text{Clay} & Al_2O_3, Fe_2O_3, SiO_2\\ \text{Chalk} & CaCO_3\end{matrix}$$

After heating to 900 degrees Celsius the next reaction takes place. Oxides are formed.

$$CaCO_3 \xrightarrow{900^\circ C} CaO + CO_2 \uparrow$$

After heating to 1500 degrees Celsius the next minerals formed.

$$\begin{array}{lcl} 2CaO & + & SiO_2 \\ 3CaO & + & SiO_2 \\ 3CaO & + & Al_2O_3 \\ 4CaO & + & Al_2O_3 + Fe_2O_3 \end{array} \xrightarrow{1500^\circ C} \begin{array}{c} 2CaO \cdot SiO_2 \\ 3CaO \cdot SiO_2 \\ 3CaO \cdot Al_2O_3 \\ 4CaO \cdot Al_2O_3 \cdot Fe_2O_3 \end{array}$$

The cement is a combination of these materials. Approximately in this proportion:

$$\text{Clin ker} \begin{cases} 2CaO \cdot SiO_2 & \text{two - calcium silicate (2CS)} & 52\% \\ 3CaO \cdot SiO_2 & \text{three - calcium silicate (3CS)} & 27\% \\ 3CaO \cdot Al_2O_3 & \text{three - calcium aluminate (3CA)} & 8\% \\ 4CaO \cdot Al_2O_3 \cdot Fe_2O_3 & \text{four - calcium alum ferrite (4CAF)} & 13\% \end{cases}$$

The concrete formed by adding water to cement powder. Following reactions illustrate this process.

$$2CaO \cdot SiO_2 + nH_2O \rightarrow 2CaO \cdot SiO_2 \cdot nH_2O$$

$$2(3CaO \cdot SiO_2) + 6H_2O \rightarrow 3CaO \cdot 2SiO_2 \cdot 3H_2O + 3Ca(OH)_2$$

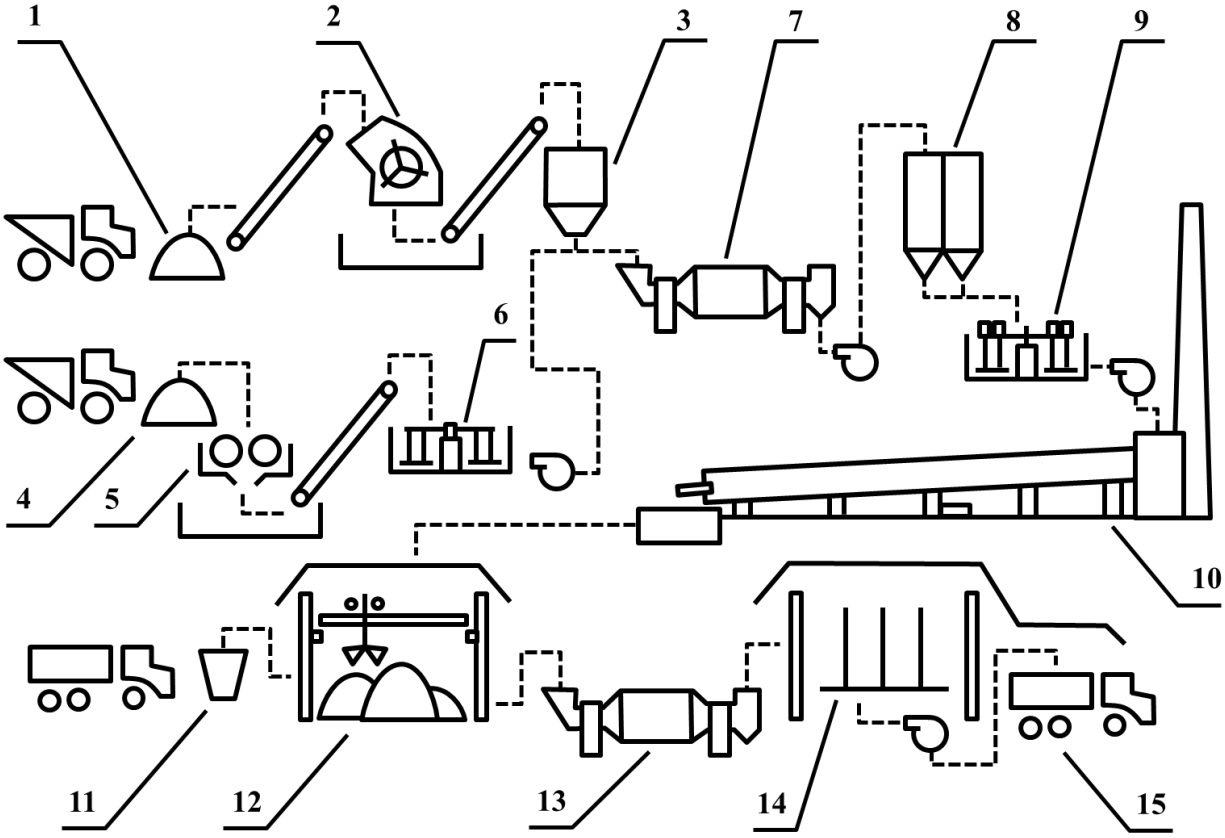
$$3CaO \cdot Al_2O_3 + 6H_2O \rightarrow 3CaO \cdot Al_2O_3 \cdot 6H_2O$$

$$4CaO \cdot Al_2O_3 \cdot Fe_2O_3 + 2Ca(OH)_2 + 10H_2O \rightarrow$$
$$\rightarrow 3CaO \cdot Al_2O_3 \cdot 6H_2O + 3CaO \cdot Fe_2O_3 \cdot 6H_2O$$

Let's look on one typical scheme of cement production called as "wet method".

Raw materials are delivered to STORAGE SILOS for chalk (pos. 1) and clay (pos. 4). The chalk is crushed in a ROTARY GRINDER (pos. 2) and transported to the bunker for raw materials (pos. 3). The clay is crushed in a ROLLER CRUSHER (pos. 5) and transported to CLAY MIXER (pos. 6). During the next action the clay with water is pumped into the raw material bunker. The suspension of clay and chalk is supplied in tube BALL MILL (pos. 7), where all components are crushed before the formation of the raw slime. The slime is pumped to SLIME STORAGE (pos. 8). The slime is mixed in the SLIME POOL (pos. 9) and feeds into the ROTARY FURNACE(pos. 10) for the roasting. The product of the roasting, the clinker is sent to a special intermediate CLINKER STORAGE (pos. 12) to reduce

temperature and the completion of chemical transformations. Special additives (e.g., gypsum) are transported to storage SILOS FOR ADDITIVES (pos. 11).



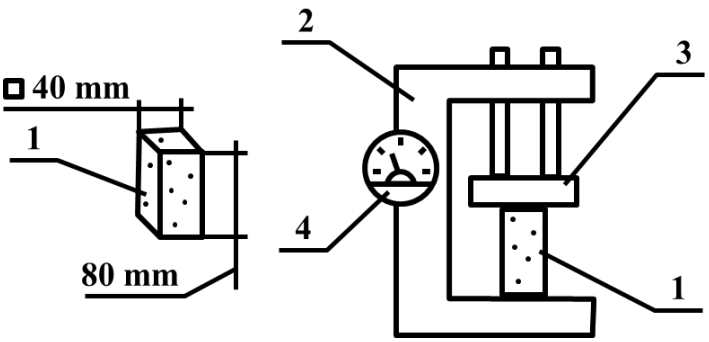
Clinker, together with additives, is crushed in a tube BALL MILL (pos. 13). Ready powdered product - cement arrives into the CEMENT STORAGE (pos. 14). Cement is prepared for transporting in special equipped PACKAGING YARD (pos. 15).

Cement divided in several brands. Brand depends on compression endurance (durability). Endurance measured in Mega Pascal.

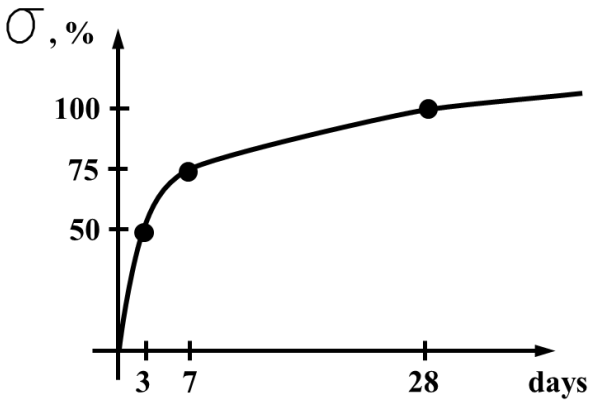
Brand	**σ, MPa**
400	**40**
500	**50**
550	**55**
600	**60**

The special device is used for endurance definition. Let’s describe the principle of this unit. The SAMPLE of material (pos. 1) is placed on the FRAME (pos. 2).

Then the sample is covered by the PRESSURE PLATE (pos. 3) and device start to influence on sample. When the sample is crushes we can see the value of endurance on special DISPLAY (SCALE) (pos. 4).



By the rule endurance measured after 28 days (after water adding). Endurance grow by this rule (graph, chart).



Practice

1. Select a variant of technological scheme from the list:

1) multi-stage crushing of natural stone materials;
2) manufacture of ceramic bricks;
3) production of porcelain glazed tiles;
4) manufacture of asbestos pipes;
5) manufacture of glass;
6) production of gypsum;
7) manufacturing of cement by "dry" process;
8) production of aggloporite gravel;

9) production of silicate bricks;
10) production of foam blocks;
11) production of roofing sheets;
12) production of concrete products (plates, pipes, fittings);
13) production of paints;
14) manufacture of furniture;
15) manufacture of wallpaper.

2. Give characteristic of selected variant of technological scheme:
   1) define the purpose of technological scheme;
   2) make an illustration of operations sequence;
   3) describe the sequence of operations;
   4) specify the base parameters of technological scheme.
3. Make report according to previous actions.

Control questions

1. Specify the list of natural building materials which you know.
2. Describe the methods for connecting separate elements in building construction.
3. Determine the role of binders in building construction.
4. Define the types of binders which you know.
5. Specify chemical bases of lime and gypsum binders.
6. Describe the general scheme of cement production.
7. Specify the list of main clinker minerals.
8. Write base chemical reactions describing the process of connecting cement with water.
9. Define the list of equipment which necessary for the technological scheme of production of cement by "wet" method.
10. Describe the principle which lies in cement branding system.
11. Describe the process of endurance definition for concrete samples.
12. Specify the law of growing of endurance of concrete samples.

USEFUL LINKS

1. https://www.911metallurgist.com/blog/single-vs-multi-stage-crushing
2. http://eippcb.jrc.ec.europa.eu/reference/BREF/cer_bref_0807.pdf
3. http://www.madehow.com/Volume-1/Brick.html
4. http://www.madehow.com/Volume-1/Ceramic-Tile.html
5. https://www.ribaproductselector.com/Docs/5/10365/external/COL210365.pdf
6. https://www.inspectapedia.com/hazmat/Asbestos_Cement_Pipe_ Manufacture.php
7. http://nzic.org.nz/ChemProcesses/inorganic/9A.pdf
8. http://eippcb.jrc.ec.europa.eu/reference/BREF/GLS_Adopted_03_2012.pdf
9. https://theconstructor.org/building/gypsum-products-properties-building-construction/14949/
10. https://fabe.osu.edu/sites/fabe/files/imce/files/Soybean/Gypsum% 20Bulletin.pdf
11. http://eippcb.jrc.ec.europa.eu/reference/BREF/clm_bref_0510.pdf
12. https://www.alibaba.com/product-detail/gravel-machinery-gravel-crushing-machine-gravel_1184687632.html
13. http://djminingmachine.com/product-5-1-sand-gravel-production-line-ru/143084
14. http://strommashina.com/about/technology-for-manufacturing-of-the-calcium-silicate-bricks
15. http://wap.autoclavecn.com/mobile_product/Autoclave_22098.html
16. http://www.metalinsulatedpanel.com/metal-panel-machines/expanded-polystyrene-machines/Grade-EPS-Block-EPS-Foam-Machine.html
17. http://www.make-in-vietnam.com/p/non-asbestos-pva-fiber-reinforced.html
18. https://www.alibaba.com/product-detail/equipment-manufacturing-of-reinforced-concrete-brick_495416641.html
19. http://www.masa-group.com/en/products/aac-production/