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TO THE ISSUE OF MATERIAL STABILITY, LONGEVITY AND DEGRADATION MECHANISM

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Abstract.

The paper provides new about such important properties of construction materials as strength, durability and degradation mechanism, it was shown that they are interconnected and are based on a common energy basis - the integral value of internal connections energy in the materials with a particular structure. Concrete strength is its integral feature estimating material in complex, starting with the formation of a solid body and ending by the resistance to various destructive factors. First of all - this is the criterion of formation and the existence of a solid body as such. The essence of a solid body development is the following one - the elementary particles composing the material under certain conditions converge at such distances when the gravity forces start to act between them. They bind elementary particles into a single unit, in a solid body with an ordered structure and provide its strength. If there is strength then all the elementary particles constituting the material, are bound by strong chemical bonds into a single unit, in a solid body with all its properties. The absence of strength means the absence of connections between elementary particles and the absence of a solid body. With the acquisition of integrity and strength a solid body gains the ability to resist various destructive factors, because the latter tend to break the links between elementary particles, and the internal energy of attraction between them that determines its strength, prevents it.

Keywords: strength, durability, failure mechanism, an integral characteristic.

Introduction.

The most valuable indicators of material quality are strength, deformability and durability, which are interrelated. The problem of material strength and durability has been studied by a large number of scientists in the world who made and make a great contribution to the science about the fundamentals of materials. However, many problems remain poorly studied because of their very great complexity.

Our research and analysis of many years concerning a vast experimental material in this area allow to have a fresh look at the fundamental properties of materials [1 ... 10].

Main part. The existing definition of material strength as the ability to resist fracture or permanent deformation when it is influenced by a variety of external forces or internal stresses and the environment does not match the physical nature of the phenomenon and the truth. The material strength is not its ability to resist breaking. This ability is gained due to strength. In fact, strength is the main characteristic of the material, determined by the size of internal sustainable relationships between elementary particles and its structure ensuring the integrity of material, the identity of oneself and the ability to resist degradation from the exposure to a variety of factors (external loads, or (and) environment). And in fact strength is the integral value of the internal connections in the material with a specific structure. Therefore, it can be measured not only in MPa, and in J/cm^3, which is the most correct from our point of view, because the essence of the phenomenon is reflected more accurately.

The value of material strength is evaluated externally. The existing definition of material strength limit as the maximum possible voltage, maintained during the test, is inaccurate. Tensile strength is determined by the load and a particular mode of its application, at which the volume of microfractures in material reaches a critical value, and then a spontaneous separation of samples into separate fragments begins. Each of these fragments has a certain strength. According to the definition, the tensile strength of the material depends on the mode of load application. This means that depending on the conditions under which the samples are tested, the same material may have different values of tensile strength. In order to eliminate the uncertainty and establish a uniform tensile strength used for practical purposes (at the designing of structures for the comparative evaluation of different materials, etc.), the mode of sample test should be regulated. The samples are made of various materials.

The real basis of the materials and their properties are the chemical elements of D.I. Mendeleev's table and the fundamental basis of origin, the existence and the properties of atoms, molecules, compounds, crystals, substances and materials is the strength in the broadest sense of the word, as a binding energy, since the strength is the integral value of internal relations energy in the material with a specific structure. The fundamental laws of physics and chemistry set the method according to which the starting material at the level of atoms and molecules affect the material structure and properties. Each chemical element of D.I. Mendeleev's table has only characteristic properties and accordingly generates only specific chemical compounds in strictly defined conditions with the structure and characteristics inherent to it. There is a natural link of chemical element atom structure and properties (nuclear charge magnitude, the number of electron shells, valence) with the energy of crystal lattices, their compounds and strength. The greater the charge of a nucleus, the number of electronic layers and the less the valence, the less is the energy of the crystal lattice concerning the chemical element bonds and their strength respectively. Any solid body has a stable structure and consists of a large number of elementary particles bound together by chemical bonds and located at a distance from each other, when the attraction and repulsion forces are balanced. In this state, the elementary particles make only small fluctuations around an equilibrium position. In this case, the whole spatial system of interconnected particles is in equilibrium, and there is no stress in it. Once an external load moves the elementary particles from a neutral position, internal stresses appear in the system directed at the particles return to its original position. The greater the displacement of particles, the greater the internal stresses opposing it. The ratio of the external voltage to the relative size of particle displacement from the neutral position $\left(\frac{\Delta r}{r}\right)$ is called the elasticity module, which characterizes the energy of chemical bonds between the elementary particles that make up the material and for the unit of its area or volume. That is why the module of elasticity is used to calculate the theoretical strength of materials, which is possible only at their ideal structure, and is determined then by the chemical bonds between the elementary particles. Studies show that the theoretical strength (R_T) of the material makes only 5 ... 19% of elasticity module (E), 10% on the average, i.e. R_T = 0,1E. If you use this relationship for the calculation of the theoretical strength of different materials, the following results will be obtained (Table. 1).

Table 1. The data concerning theoretical and technical strength of materials.

Material	Class	Elasticity, MPa $\left(\frac{J}{cm^3}\right)$	Theoretical strength, R_T = 0,1E, MPa	Technical strength, MPa		$\frac{R_T}{R_\Phi^P}$	$\frac{R_T}{R_\Phi^C}$
				tension, R_Φ^P	compression, R_Φ^C		
Heavy concrete of natural curing	B15	24000	2400	1,6	19,3	1500	124
	B25	29000	2900	2,1	32,1	1381	90
	B40	36000	3600	3,6	57,4	1000	70
	B60	40000	4000	4,4	77,1	909	52
Labrador	-	87500	8750	-	100	-	87
Granite	-	75000	7500	-	157	-	48
Limestone-1	-	30500	3050	-	40	-	76
Limestone-2	-	16500	1650	-	23	-	72
Steel	AT IV	196000	19600	900	-	22	-
	AT VI	186000	18600	1230	-	15	-
	ATVII	186000	18600	1420	-	13	-

As can be seen from Table 1 the theoretical strength of materials is much higher than a technical (real) one, which indicates their huge unused capabilities. The ratio the theoretical strength to the actual one can judge on the defects in the material structure. The more the ratio is, the more defects the structure has. According to this criterion, the most perfect structure is presented by metals, followed by some rocks (e.g., granite) and high-strength concretes. The concretes with low durability have the most imperfect structure. Since the foundation of any material strength is the binding energy, the strength is an objective quantitative measure of existence of different forms of matter existence. The state of matter is determined by the amount of energy that binds the constituent components into a single unit, and by a bond strength. If, for example, the value of main mineral binding energy of a cement stone $3CaO \cdot SiO_2$, $2CaO \cdot SiO_2$, $3CaO \cdot A1_2O_3$ and $4CaO \cdot A1_2O_3 \cdot Fe_2O_3$ is equal to 5239,2; 4139,3; 6246,6 and 9715,5 kJ/mol respectively, then this is a solid state of the matter. If the binding energy between water molecules, including hydrogen one, makes 40 ... 80 kJ/mol, then the sate is a liquid one. For a gaseous state the binding energy between molecules makes only 8.00 ... 16 kJ/mol. The bond strength between elemental particles in a solid state is three orders higher in comparison with relation magnitude between the molecules of the substance in a gaseous state. Therefore, the development of solid bodies is impossible if a corresponding strength level of bonds is not reached between the atoms of chemical elements or initial raw ingredients. In this regard strength is the criterion of solid bodies development. If, under certain conditions and combinations the chemical elements or raw materials really united into a single physical structure, thus strong chemical, physical and mechanical connections appeared between them, which will provide a certain strength to a developed structure. If this condition is not met, then no solid body appeared. Varying the distances between the atoms or the molecules of chemical elements and the energy of their interaction by any method (thermal or mechanical one) materials or substances can be converted from one state to another. The most obvious change of a matter state under the influence of pressure or temperature takes place in liquids and gases. With respect to solids, this is most clearly presented by their heating up to high temperatures. At a continuous feeding of heat to the material the distance between the atoms of chemical elements increases and the relations between them weaken. The material is destroyed and it happens till the reach between elementary particles of such a critical value of the binding energy, at which a solid body cannot exist, and it moves to another state, in a melt, that is, it is destroyed in fact and cease to exist as such with all its properties. In regard with the things mentioned above an inverse process is logical - the convergence of chemical element atoms in a solid state to a certain extent which will increase the binding energy between them, the density and the strength of materials.

Strength and durability are identical concepts. Therefore, when they speak just of material strength, it means that it was in normal conditions. When it comes to cold resistance, corrosion resistance, biological stability of the material, etc., in these cases the same material strength is meant, but under the impact of frost and corrosive environments. In this regard and in fact, for example, the cold resistance, the corrosion resistance of the material, etc. should have a single definition of strength which is the integral value of internal connection energy in the material with a specific structure. The value of the internal connections energy in the material with a specific structure, determines, ceteris paribus, their ability to resist the degradation when exposed to cold, corrosive environments, etc., which is estimated according to the change of material strength. Durability is a generic term that includes frost-resistance, corrosion resistance, the biostability of materials, etc. Therefore, the strength and the durability of materials are closely related. That material is a durable one, the strength of which remains a stable one under in time under all environmental conditions. The energy of internal relations in crystalline materials (strength) determines the pattern of their behavior under load and destruction. In accordance with the laws of physics the repulsive forces between the atoms of chemical elements in materials have virtually unlimited values, while the forces of attraction between them are limited and therefore they are the weakest link in the structure of materials. This means that the strength and the deformability under tension play a major role in the destruction of materials at any kind of external influence, including the heat one. The strength is determined by the weakest component of the structure - the integral value of internal connection energy in the materials with a specific structure, that is, by the internal cohesion forces of the forming components, which characterize tensile strength. The reduction of internal connections in materials up to a critical value by their heating up to high temperatures occurs under the influence of heat, and their break happens at external load application - under the influence of mechanical energy, in particular under the influence of tensile or shear stresses. However, the maximum shear strength is considerably higher than tensile strength. In this regard, the breaking of internal relations is most likely. The breaking the internal connections, discontinuity structure of materials is due to the excess load of the tensile strength. The further development of appeared microcracks occurs both according to tearing off and shift mechanisms. Any crystalline body is not an abstract mathematical figure, as it is often represented, for example, in the strength of materials, and the real physical structure is formed strictly by physical laws. And therefore its interaction with similar structures is subject to the laws of physics, not mathematics. In this case the observance of mathematics laws leads to erroneous conclusions. Thus, in accordance with the mathematical conclusion of material strength if, for example, a uniaxial external load is applied to a rock sample (strictly according to the sample axis), the corresponding stresses therein occur in the direction of this load action. There are no material stresses in other directions. However, this conclusion is not true. We found out that at the exposure of any external load, including uniaxial one on crystalline materials a complex stress state happens inside. For example, during the application of an external uniaxial tensile force to a material tensile strains and stresses appear in it, calculated from the external load according to the rules of material strength, while the internal stresses tightening the bulk material, act as a rule as the response to external influence resistance. This means that the tensile stresses in the materials are determined by the internal forces of attraction between the atoms of chemical elements and their components, resulting from the displacement in the direction of particle removal from its initial energetically favorable position. A material can not be destroyed from the internal volumetric compression stress, and in this case the destruction occurs only from the external tensile force. Similarly, at external uniaxial compressive stress the compressive strains and stresses occur in materials calculated from an external load, in accordance with the strength of materials provisions and simultaneously volumetric internal expanding stresses which are determined by internal volumetric forces of repulsion between the atoms of chemical elements arising from the displacement of elementary particles from its initial energetically favorable position in the direction of convergence. If an external compressive load is volumetric and evenly distributed, then the volumetric repulsion internal forces arising between the atoms of chemical elements provide a very high unlimited strength ideally. If the external compressive load on a material is uniaxial one, these internal volumetric repulsion forces will counteract the external compressive force in the direction of its action and at the same time they serve as the main cause of material destruction in other areas without an external opposition, which is confirmed by the direct experiment. During the experiments a polymer soluble ball with the diameter of 70 mm and the density of ρ_c = 1760 kg/m^3 was subjected to one-based vertical compression using a 10-ton press (Fig., Tab. 2).

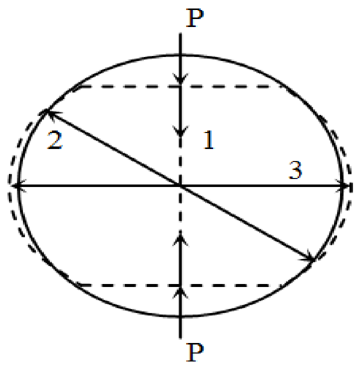

Fig. The scheme of a polymer soluble ball deformation test and distribution under uniaxial vertical compression; 1, 2, 3 - - deformation measurement directions.

Table 2 : Test results of a polymer soluble ball.

Item №	Load, t	Absolute deformations of a ball, mcm, in the direction		
		1	2	3
1	6	700	27	113
2	7	900	39	131
3	8	1500	87	199
4	9	1900	86	289

The experiment results (Table 2) confirm that the external uniaxial vertical load on a ball causes the appearance of internal volumetric expanding stresses which oppose the external pressure load in the direction of its action, and in other directions, not only perpendicular to the direction of external load action, invokes volumetric expansion deformations (Fig.).

The durability of any material is directly related to the process of destruction. And so the knowledge about the process operation is necessary to control it in order to its slowing down or exclusion and the provision of structure and building high durability. Our studies show that the mechanism of material destruction is a single one in all cases at thermal, physical, chemical, mechanical and combined exposures. It is based on Newton's third law: "Any external radiation on a physical body is always opposed by the inner, volumetric energy adequate opposition". The process starts with the thinning of material structure when the distance between the atoms of chemical elements, their components, weakening is increased and then the breaking of internal links between them and the deformability increase takes place. With the increase of external influence on the materials the thinning increase, the internal potential possibilities weaken and the breaking of continuity starts in real structure materials, associated with the appearance of cracks and other micro-defects.

As soon as the number of external destructive power or the amount of microfractures for real bodies reach critical values, that is the tensile strength or the integral value of internal relation energy in materials is achieved, their potential resistance for destruction is exhausted, and the samples are divided into separate elements. It is necessary to distinguish between total material destruction with any structure from the physical point of view - it is their collapse into the elementary particles that make up their physical basis, the binding energy between them reaches such critical values when a solid body becomes a liquid one. This type of destruction always occurs by material heating with any structure prior to melt, and the materials with a perfectly smooth and perfect structure are hypothetically possible under the influence of an external load. The criterion of the destructive process evaluation for this embodiment may be the amount of thermal energy in J, required for 1 cm3 of the material. It is directly related to the melting temperature of the materials. The higher the melting point, the greater the internal bond energy and more thermal energy is necessary from the outside, in order to thin the material structure sufficiently and reduce the energy of the internal connection to such critical value at which a solid body can not exist. In the material with an ideal and a homogeneous structure all internal bonds between the atoms of chemical elements and its components are perfectly stable and have a uniform strength, and when the limit of the theoretical strength is reached they are broken instantly and simultaneously. Therefore, during the destruction of the material with an ideal structure from an external load it should be divided into separate atoms of chemical elements hypothetically, that is, to be converted into a gaseous state, that is unlikely by physical laws. As described above, the state of matter is determined by the energy of internal relations in the material and during its reduction the material turns gradually from a solid into a liquid state and then into a gaseous state. Only artificially created substances may turn directly from a solid state to a gaseous one. These substances cannot exist in normal terrestrial conditions (artificial ice, naphthalene, and other substances). The removal of gases and water from material is also possible long before its melting, for example, during the decomposition of carbonates, but basically rock materials existing millions of years, cannot pass directly from a solid into a gaseous state, bypassing a liquid one. As with the increase of external impact the energy of internal relations in materials is gradually reduced, then according to the laws of physics, materials must proceed gradually, first into a liquid, and then into a gaseous state.

Summary. Under the influence of the external load and the achievement of the theoretical strength the material with an ideal structure should probably transform into a liquid state, that will be the end result of its destruction, that is, it must be divided into individual atoms, ions, anions, cations, radicals and other elementary particles poorly interconnected and constituting the liquid-type of a substance with melt properties.

An incomplete destruction of materials with a real defect structure is their partial division into separate relatively large parts, each of which has rather sufficient strength, and their size is determined by the degree of perfection and the homogeneity of material structure. This type of destruction occurs under the impact on real materials of an external load, or (and) the physical-chemical effects of the environment. Because of unequal strength of all internal links between the constituent components in the materials with defective and non-uniform structure, they are destroyed in the weakest places. The elements of the samples with the most robust internal connections remain intact. Subsequently materials are separated into them. With the increase of perfection and a structure homogeneity all internal material communications are aligned, and they break down into smaller pieces during destruction. The criterion of concrete technical capacity evaluation with an incomplete destruction is the amount of operation performed by a load, at which the critical total volume of microfracture is reached in material, after which the spontaneous separation of the samples into separate elements starts.

It was found that numerous materials are destroyed as the result of the occurrence and the development of microcracks in a structure under load. Starting from Griffith and currently the destructive process is estimated by the length of microcracks. Once their total length reaches a critical value, the samples are divided into separate parts, which does not correspond to the physical meaning and truth. Each crack at the time of its formation is the volume which is characterized by length, width and depth. A volume can not be measured by only one parameter - the length. Thus it is proposed to evaluate the process of destruction not by the length of microcracks but by their volume or the volume of microfractures. Then the volume of microfractures required for the final collapse of the specific material into parts is proposed to assess by the magnitude of the specific work required for this process implementation, namely:

$$A_p = \int_0^{\varepsilon_p} R d\varepsilon$$

At the same time the value of "A_p" characterizes the limit of material technical capabilities. This limit depends not only on their strength but also on deformability.

Similarly, the process of material destruction takes place during the physical and chemical impacts of diverse aggressive factors on them. The same characteristic signs of destruction as the material decompression, the weakening of internal linkages and the increase of its deformability, the structure integrity violation, the weakening of durability and the disintegration into parts are repeated here, but the energy of chemical reactions, physical processes, the vital activity of bacteria and micro-organisms, and so on are spent for it.

Conclusions. Thus, the article present the basic materials which can serve as the basis for the rethinking and a new view about the strength, durability and the mechanism of material destruction with any structure, about their relationship and a common energy basis of all materials and their properties..

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