https://doi.org/10.26906/znp.2018.50.1067

UDC 691.327.014.13

Fenko O.G., *PhD, Associate Professor*
ORCID: 0000-0002-3175-2892 fenko.aleksey@gmail.com
Yurko I.A., *PhD, Associate Professor*
ORCID: 0000-0003-3758-206X ilona.yurko@gmail.com
Karabash L.V., *PhD, Associate Professor*
ORCID: 0000-0003-1699-5930 l.v.karabash@gmail.com
Poltava National Technical Yuri Kondratyuk University
Yurko P.A., *PhD, Research Employee*
ORCID: 0000-0002-3485-435X pa.yurko@gmail.com
State research institute of building constructions

THE INFLUENCE OF OWN STRESSES ON TENSILE CONCRETE STRENGTH

Based on experiments results brittle duralumin samples, effect on stresses concrete (mortar) strength caused by non-uniform cross-section shrinkage (when dried) or expanding (when moistened) was inevitable. Various authors' experiments results diversity on concrete (mortar) tensile strength of moistening and drying effect were analyzed. Reasons for increasing air-dry concrete (mortar) strength storage at beginning of humidification were explained. Wetting sample duration (intensity) effect on concrete strength was analyzed in detail and opposite results causes on concrete strength moistening (drying) effects were obtained and justified.

Keywords: *own stresses, concrete strength, concrete water saturation, shrinkage, creep.*

Фенко О.Г., *к.т.н., доцент*
Юрко І.А., *к.т.н., доцент*
Карабаш Л.В., *к.т.н., доцент*
Полтавський національний технічний університет імені Юрія Кондратюка
Юрко П.А., *к.т.н., с.н.с.*
Державний науково-дослідний інститут будівельних конструкцій

ВПЛИВ ВЛАСНИХ НАПРУЖЕНЬ НА МІЦНІСТЬ БЕТОНУ ПРИ РОЗТЯЗІ

Спираючись на результати дослідів над крихкими дюралюмінієвими зразками, доведено неминучість впливу на міцність бетону (розчину) напружень, викликаних нерівномірною по поперечному перерізу усадкою (при висушуванні) або набряканням (при зволоженні). Проаналізовано різноманітність результатів дослідів різних авторів із впливу зволоження і висушування бетону (розчину) на міцність при розтязі. Пояснено причини збільшення міцності бетону (розчину) повітряно-сухого зберігання на початку зволоження. Детально проаналізовано вплив тривалості (інтенсивності) зволоження зразка на міцність бетону та обґрунтовано причини отримання протилежних результатів дослідів впливу зволоження (висушування) на міцність бетону.

Ключові слова: *власні напруження, міцність бетону, водонасичення бетону, усадка, повзучість.*

Introduction. Own structural stresses influence on concrete strength, caused by long compression or tension continued, was investigated in many experiments. Unevenly distributed over cross-section of own stresses influence on concrete strength has not been studied, although it is advisable to consider factor that determines concrete strength.

Recent sources analysis of research and publications. To main factors influencing own stresses cross section occurrence and uneven distribution, except for concrete composition and conditions for its hardening and storage, concrete age [1], undoubtedly concrete samples water saturation and drying are inclued [2 – 4]. Many authors devoted their works to investigation of concrete samples moisture content influence on their compressive strength [5 – 8].

Analysis and justification of unevenly distributed intrinsic stresses influence on concrete strength under compression caused by shrinkage or expanding are given in [9].

Moisture influence results on concrete strength under tension, which do not have significant contradictions, are given in works [10 – 12]. It should also be noted that in all above papers, unevenly distributed influence analysis on proper stresses cross-section on concrete strength during tension was not carried out.

Among many factors that influence concrete strength under tension, it is rather difficult to isolate influence of unevenly distributed in own stresses cross-section. To prove effect of such own stresses on material strength, experimental studies were carried out on brittle (silicate) aluminum alloy. In cylindrical specimens, intrinsic stresses fields with opposite sign were created in comparison with own stresses fields caused by temperature distribution unevenness in cross-section during samples hardening under natural conditions [13].

Confirmation of own stresses influence on material strength is result of experiments carried out with own stresses duralumin samples higher strength with opposite sign to their own stresses that arise under normal hardening conditions. Basing on duralumin experiments results, influence of unevenly distributed intrinsic stresses on concrete strength under compression was proved [9].

Identification of general problem parts unsolved before. Own stresses unevenly distributed cross-section influence on concrete tensile strength was not investigated.

The research **goal** is to determe impact unevenly distributed over own section stresses on concrete strength in tension.

Basic material and results. Difference in own stresses influence (unevenly distributed cross-section) on concrete strength in compression and maturation is that at such stresses compression can both increase and decrease concrete strength (depending on nature of cross-section distribution), and when tensile, at any distribution of own stresses on cross-section, concrete strength will decrease.

It is no coincidence that various conclusions were drawn from experiments on moistening (or drying) effect on concrete strength when tensile. Shestoperov S.V. and Lyubymova T.Yu. studied moisture influence on tri-calcium aluminate mortar strength. Authors came to conclusion that when wet samples dry in atmosphere of saturated vapor or when immersed in water mortar tensile strength decreases, respectively, increase in moisture samples.

Tsiskreli G.D. [14] in experiments on moistening and drying influence on concrete strength received opposite results. Four samples groups were made for research, which two groups were stored in an aqueous medium, and two ones in air. Each pair was tested in storage by the first group. Water storage was dried before testing by the second group, and dry storage was saturated water by other group.

As tests result, average samples of water storage tensile strength during drying decreased from 2.33 MPa to 1.93 MPa. Average samples of dry storage with moisture tensile strength increased from 1.13 MPa to 1.38 MPa. Such opposite results can be explained by their own stresses samples state at test time.

In experiments Leshchinsky M.Yu. [2] samples were stored in moist environment for ninety days. During this period, moisture managed to penetrate sample center, and there was significant own stresses relaxation. Before test, samples were dried to achieve constant weight at t = 60°C. During this period, there were own stresses caused by intensive concrete shrinkage on samples surface: external layers were tensiled, and internal compressed.

When loading such samples, external layers will be more extended. Sample will destruct at lower external load than sample without its own stresses will do. When further drying, internal layers will decrease in size, which will reduce own stresses values, and as consequence, increase tensile strength. Such conclusions were confirmed by experiments of Leshchinsky M.Yu. (Fig. 1).

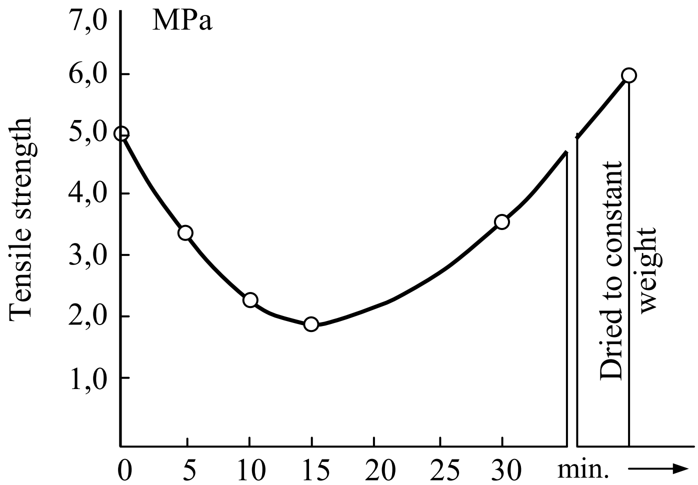

Figure 1 – Water-saturated samples prolonged drying influence on mortar eensile strength [3]

Moisture influence on concrete (mortar) strength experiments characteristics during tensile analusis, an unevenly distributed stress on concrete strength [3 – 5, 14] influence analysis were not conducted.

When water-saturation is created, own stress with opposite sign comparatively with stresses arises when drying concrete. Moistening sample correlates with external layers. External layers of moisture increase (expands) in size, tensioning internal layers.

Sample central part will be overloaded with tensile force and from it the destruction begins, when load of such a sample. Thus, sample will destruct at lower load comparatively with sample without having its own stress. Water enters sample central part when further moisture and thereby reduces its own stress and in end they can go down to zero.

Own stresses influence on mortar strength depends on stress state at wetting beginning. For example, Maltsov K.A. moisturized air-dry storage samples. In such samples, external layers are tensile (shrinkage), and internal layers are compressed. First torn external layers, when tested for breaking of such samples reduce entire sample strength.

When moisturizing such sample, external layers expend first reducing their own stresses, and as consequence, increasing strength. When moisture passes to sample depth, central fibers 1 swell, creating their own stresses in sample: internal fibers are compressed, and external tensiled reducing sample strength. Such conclusions are confirmed by Maltsov K.A. experimentally [3] (Fig. 2).

Practically the same influence character of unevenly distributed along stresses section on concrete strength is shown in experiments by Arkhypova A.M. [4]. Moisture uneven distribution influence possibility on cross section of sample on concrete (mortar) tensile strength is also considered. But such impact analysis is not provided (Fig. 3).

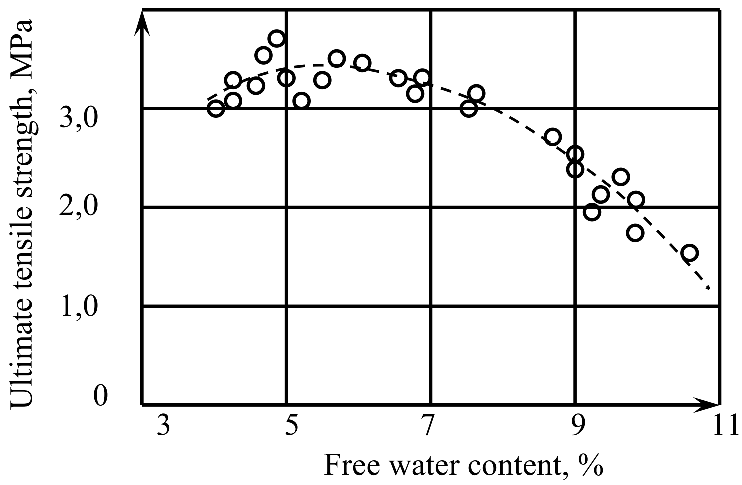

Figure 2 – Mortar strength -moisture dependence

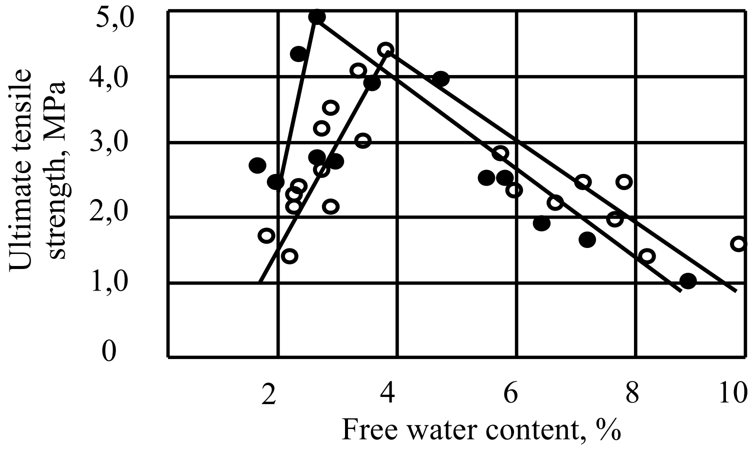

Figure 3 – Water saturation influence on cement mortar tensile strength

Similar results were obtained by Moskvin V.M. and Basement A.M. in water influence study saturation on concrete strength. Air-dry storage concrete disks were tested, which were humidified during test up to 6% [14] (Fig. 4).

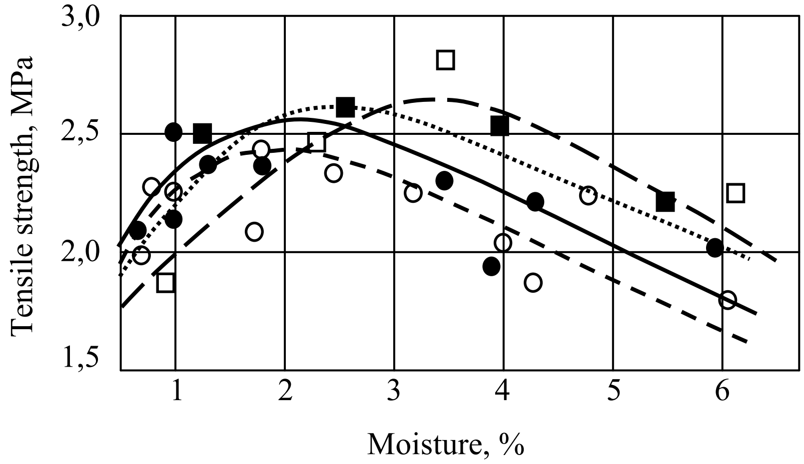

Figure 4 – Moisture effect on concrete tensile strength

Some researchers believe that changes in concrete strength during wetting (expanding) and drying (shrinkage) are affected unevenly distributed by deformation section, but such influence mechanism analysis is not given either in bending tests [14] or in compression [7, 10].

Mileykovska K.M. in its experiments, strength reduction during concrete moistening binds to concrete deformation, but coupling deformations mechanism with water saturation with decrease in strength is not clear. It was concluded that, with expanding termination, decline in concrete strength stops, and with sufficiently long water saturation, strength is completely restored, which can be explained by their own stresses relaxation.

Experiments results disadvantage on their own stresses influence on concrete strength (mortar) is that tests were carried out in short time. During experiment, as a rule, there is not enough time to manifest either own stresses concrete creep or relaxation, and they affect concrete (mortar) strength.

Similar experiments were carried out on cement mortar samples. Samples were dried at 105-110 ° for constant weight and stored in desiccator after making and steaming. For each test stage, samples were saturated with different fluids (water, ethanol, benzol, calcium chloride water solution) for several days. It should be noted that at tests beginning there was in samples practically absent (or brought to minimum value) their own stresses, unevenly distributed across cross-section.

When moisturizing such samples, external layers swell first. As external layers expand internal layer tension expend. When loading such sample with tensile force, internal layers will be overloaded and destroyed first, therefore, sample l withstands less load compared to sample without its own stress. Further, fluid penetration, for example, leads to increase in size (swelling) of sample central part, which leads to decrease in difference in sizes of external and internal layers, and as consequence to reduce their own stresses. As own stresses reduction result, samples l withstands greater external tensile force.

It should also be noted that at the beginning sample wetting, during swelling external layers caused creep when internal layers are tensed. External layers were reduced in size from creep to compression. As result, with further expanding (mainly internal part), there are own stresses: sample internal part is compressed and outer is stretched and sample strength when tensed after reaching maximum value will decrease gradually. Such conclusions were confirmed experimentally [14] (Fig. 5).

Sown in Fig. 5 dependencies confirms that moisture (drying) experiments on effect results on concrete (mortar) strength depend on state in which stress state is sample in test. So, when testing liquid from saturation effect dry state to moisture content 2%, the mortar strength will decrease, and when tested with moisture content of 4% to 6% strength will increase due to moisture.

When testing samples saturated with liquid more than 14%, mortar strength will decrease (Figure 5). Such results explain conclusions variety obtained in water saturation (expanding) and drying (shrinkage) effect study on concrete (mortar) strength.

As experiment showed, liquid chemical composition did not affect change character (sequence) in mortar strength with increasing saturation. Cement prior chemical process involvement to creation of their own stresses when wetting and drying samples is proved by experiments results carried out over tuff [14]. Tuff samples strength dried to constant weight 24.8 MPa, samples stored in air-dry medium had strength 9.8 MPa, and when samples were saturated with water, strength was reduced to 5.6 MPa. Samples were pre-saturated with water, and then completely dried (to constant weight) showed strength 24.7 MPa. Thus, reduction in strength as saturation result with water was completely reversible. Similar picture of decrease in strength under water saturation is observed in artificial stone materials, for example, in brick.

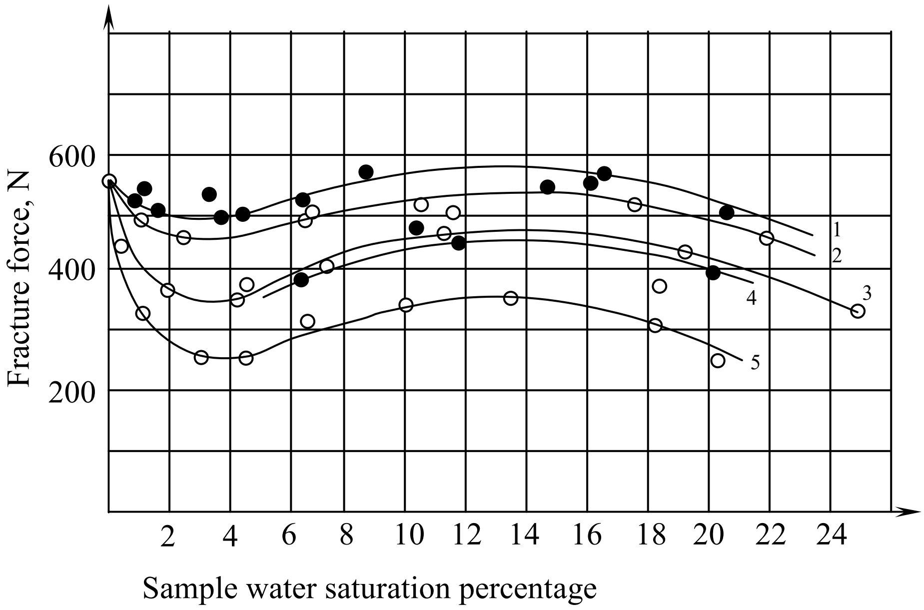

Figure 5 – Mortar strength depends on water saturation different fluids
1 – kerosene and benzol; 2 – ethanol; 3– water;
4 – saturated calcium chloride water solution;
5 – 0,5% calcium chloride water solution

Such conclusions are confirmed on cores with moisture 8%, taken from hydrosystem at depth 40 m under water. With moisture increase 1.5 – 2.5% (due to uneven moisture in cross section), core strength decreased. Cores further storage in air-dry environment has led to increase in cores strength [14].

Both experimental and theoretical additional studies are required in own stresses influence issue on concrete strength.

It should also be noted that shrinkage and expending effect described interpretation on concrete strength with tension does not claim comprehensive explanation of this issue and has in addition adsorption effect and compression by capillary pressure forces.

Conclusions. Analysis of unevenly distributed stresses in concrete (caused by shrinkage or expending), which is unevenly distributed over cross section, confirms and sufficiently substantiates their influence on concrete tensile strength.

References

1. *Вплив тридцятип'ятирічного розтягу на деформативні властивості бетону / Г. О. Фенко, О. Г. Фенко, А. В. Гергель, В. В. Пашинський, Р. О. Повзик // Збірник наукових праць. Серія: Галузеве машинобудування, будівництво. – Полтава, ПолтНТУ, 2010. – Вип. 2(27).– С. 39 – 42.*
2. *Лещинский М. Ю. Влияние водонасыщения на сопротивление разрыву затвердевших цементных растворов и бетонов / М. Ю. Лещинский // Докл. АН СССР. – 1956. – Т. 109. – № 3. – С. 521 – 523.*
3. *Мальцов К. А. Влияние водонасыщения на прочность бетона / К. А. Мальцов // Гидротехническое строительство. – 1954. – № 8. – С. 21 – 25.*
4. *О влиянии воды на прочность бетона / А. М. Архипов, К. А. Мальцов, И. Б. Соколов, П. Г. Старицкий // Докл. АН СССР. – 1959. – Т. 109. – № 3. – С. 521 – 523.*
5. *Влияние водонасыщения на изменение прочности бетона длительного твердения / Ю. Н. Воронов, В. А. Панасюк, С. С. Макарова, В. М. Виноградский // Вісник Одеської академії будівництва та архітектури. – Одеса, ОДАБА, 2009. Вип. 35. – С .64 – 70.*

6. *Bartlett F. M. Effect of Moisture Condition on Concrete Core Strengths / F. M. Bartlett, J. G. MacGregor // ACI Materials Journal. – 1994. – 91(3). – P. 227 – 236.*
7. *Popovics S. Effect of curing method and final moisture condition on compressive strength of concrete. ACI Journal. – 1986. – 83(4). – P. 650 – 657.*
8. *Russell J. J. Einfluss des Feuchtigkeitsgehaltes auf die Druckfestigkeit Kleiner Gipswьrfel / J. J. Russell. – Berlin: Zement-Kalk-Gips. – 1960. – № 8. – 345 p.*
9. *Fenko O. The influence of its own stresses on concrete strength under compressing/ O. Fenko, O. Krupchenko, I. Yurko // Збірник наукових праць. Серія: Галузеве машинобудування, будівництво. – Полтава, ПолтНТУ, – 2016. – Вип. 2 (47). – P. 155 – 161.*
10. *Chen X. Effect of moisture content on compressive and split tensile strength of concrete / X. Chen, W. Huang, J. Zhou // Indian Journal of Engineering and Materials Sciences. – 2012. – Vol. 19. – P. 427 – 435.*
11. *Glucklich J. Effect of Moisture Content on Strength and Strain Energy Release Rate of Cement Mortar/ J. Glucklich, U. Korin // J. Amer. Ceram. Soc. – London, 1975. – Vol. 58. – № 11-12. – P. 517 – 521.*
12. *Hotta H. Influence of drying and water supplying after drying on tensile strength of cement mortar / H. Hotta, K. Takiguchi // Nucl. Eng. Des. 156(6). – 1995. – P. 218 – 228.*
13. *Фенко О. Г. Вплив власних напружень на міцність матеріалів / О. Г. Фенко, Г. О. Фенко // Ресурсноекономні матеріали, конструкції, будівлі та споруди: збірник наукових праць. – Рівне: НУВГП, 2013. – Вип. 25. – С. 466 – 471.*
14. *Цилосани З. Н. Усадка и ползучесть бетона / З. Н. Цилосани. – Тбилиси: Мецниереба, 1979. – С. 44 – 84.*