MEASUREMENT AND DETERMINATION OF STRENGTH OF LOAD-BEARING STRUCTURES MATERIALS BY SHEAR TEST METHOD

Alena Rotaru

All-Russian Scientific Research Institute for Civil Defence and Emergencies of the EMERCOM of Russia
alenarotaru@mail.ru

Abstract

The strength of load-bearing and enclosing structures largely depends on the parameters of their materials. Complex shear testing of concrete is a non-destructive method used to determine the parameters and quality of the mixtures used with high accuracy. This concrete testing method has become widespread due to its versatility and convenience. The material strength is tested by directly impacting the concrete of the structure and causing its partial shearing. During the test, the force needed to tear off a fragment of the structure using a leafed anchor embedded in the bore hole is determined. This method can provide more accurate data on the concrete strength to make a decision on the need for further operation of the building. The concrete test to be shear tested must be located at a sufficient distance from pre-stressed rods. In addition, the test area should not be subjected to heavy operational loads.

Keywords: concrete strength, shear test method, anchor, calibration curve, non-destructive testing, device.

I. Introduction

The shear test method is used to test the strength of concrete. The shear test method has advantages over non-destructive methods for determining the strength of concrete. Modern non-destructive methods use various indirect characteristics (ultrasound propagation rate, diameter of the imprint left on concrete upon impact, etc.) to determine the strength of concrete. The method is based on an empirical proportional relationship between the concrete strength and the pullout force of a special anchor with an expanding cone. The lack of a concrete destruction physical model during the shear test is challenging to find ways to improve the accuracy and reliability of the results. The purpose of the study is to develop a physical model of concrete destruction to determine the design strength by shear testing.

II. Methods

During shear testing, an anchor usually breaks out concrete in the form of a truncated cone, indicating a cleavage failure. This means that the concrete tensile strength is less than its shear strength. Otherwise, it would be a shear failure.
Leafed anchors, which can be of different sizes, are used to apply a pullout force. The anchors are inserted into drilled holes in the measurement area. As in the previous case, a device measures the fracture force. The compressive strength is calculated based on the relationship expressed by the formula

$$R=m1*m2*P$$

where:
m1 is the maximum size factor of coarse filler,
m2 is the conversion factor for compressive strength. It depends on the concrete type and strength gain conditions.
P is the fracture force obtained by testing. This method is one of the most popular ones as it is quite versatile. It ensures to test any part of the structure, since a flat surface is not a must. In addition, it is easy to fix a leafed anchor within the concrete mass manually. However, there are some limitations, such as:

• Dense structure reinforcement, in this case the measurements will be inaccurate.
• Structure thickness, it should be twice the length of the anchor. The ONIX-1.OS device is used for concrete shear testing, as shown in Pictures 1-2.

Picture 1: *Shear test method using ONIX-1.OS*

Picture 2: *Shear test method (crack formation)*

During shear testing, the anchor breaks out concrete, indicating a cleavage failure as shown in Pictures 3–4.

Picture 3: *Breaking out of concrete during a shear test*

Picture 4: *Breaking out of concrete during a shear test*

III. Results

Using the data recorded during the study, we can evaluate the strength of the above material based on the applied load at which shear occurs. The force breaking off a concrete fragment as a result of shearing is multiplied by a correction factor. It is calculated using the following formula:

$$\gamma = h^2/(h - \Delta h)^2$$

where h is the anchor depth,
Δh is the slip value.
If the maximum length of the material fragment broken off during the test is more than twice the minimum length, the result is deemed indicative. The same applies, if the hole depth exceeds the anchor slip value by 5% or more. Indicative values cannot be used to determine the strength class of a material. The tests are deemed invalid, if the tear depth differs from the anchor length by 10% or any reinforcement rod is found at a distance within the hole depth. During the works, the measurement results are recorded in a table, as shown in Table 1.

Table 1: *Measuring concrete strength by shear testing*

Structure	Test site No.	Shear force, MPa	Average strength, MPa
Reinforced concrete column No. 1	1	53.6	51.24
	2	52.1	
	3	50.6	
	4	48.2	
	5	48.9	
	6	49.9	
	7	51.1	
	8	52.9	
	9	53.9	
Reinforced concrete column No. 2	1	44.9	45.25
	2	43.4	
	3	45.6	
	4	46.7	
	5	44.8	
	6	46.7	

Structure	Test site No.	Shear force, MPa	Average strength, MPa
	7	45.8	
	8	44.4	
	9	45.0	

Strength testing of reinforced concrete columns in 9 sections yielded values from 45.25 MPa to 80 MPa. The strength of concrete becomes constant after achieving the concrete strength of about 50 MPa, as reported in various regulations.

IV. Conclusions

It was established that the empirical dependence between concrete compression resistance and anchor pullout force assumed for shear testing of concrete is only possible with a linear dependence between the concrete compressive and tensile strength. However, the actual relationship between the concrete compressive and tensile strength is not linear, so for relatively weak concretes, the potential compressive strength overestimation due to the empirical relationship is neutralized by a reduction factor. The more accurately tensile strength is converted to compressive strength, the more accurate the calculation results using the developed model and empirical pullout force values. One of the most accurate methods for testing the strength of structures. The shear test method allows to determine the forces needed for local concrete failure as an anchor element is pulled out from it. This method has disadvantages, such as high labor intensity and unsuitability for areas with dense reinforcement, as well as partially damaged structures.

References

[1] Kralik J., Kralik J., Probability Assessment of Analysis of High-Rise Buildings Seismic Resistance, Advances in manufacturing science and engineering, Advanced materials Research, 2013.

[2] CSN EN 1992-2 Eurocode 2 – Design of concrete structures, Concrete bridges, Design and detailing rules, 2005.

[3] Non-destructive testing: reference book: in 8 volumes. Vol. 3: Ultrasonic testing – Ed. 2, revised and amended. – Moscow, Mashinostroenie, 2008, 864.

[4] Szonova S.A., Nikolenko S.D., Zyazina T.V., Chernyshova E.V., and Kazbanova I.M., Srength test of the industrial building's load-bearing structures, Journal if Physics: Conderence Series, 2373, 2022.

[5] Litvinov A.E., Novikov V.V., Solod S.A. and Chukarin A.N., Russian Engineering Reseach, 39 (2), 2019, 158-9.

[6] MSL Engineering Limited, Doc ref. C237R001 rev. 1 Nov. 2004, Assessment of repair techniques for ageing or damaged structures.

[7] N-001 Structural Design, NORSOK, Rev. 2004.

[8] Kaloop, M.R., Roy,B., Chaurasia, K., Kim, S.-M., Jang, H.-M., Hu, J.-W., Abdelwahed, B.S., Shear Strength Estimation of Rein- force Concrete Deep Beams Using a Novel Hybrid Metaheuristic Optimized SVR Models. Sustainability 2022, 14, 5238.

[9] Kachouh, N., El-Maaddawy, T., El-Hassan, H., El-Ariss, B., Shear Behavior of Steel-Fiber-Reinforced Recycled Aggregate Concrete Deep Beams. Buildings 2021, 11, 423.

[10] Tariq, M., Khan, A., Ullah, A., Shayanfar, J., Niaz, M., Improved Shear Strength Prediction Model of Steel Fiber Reinforced Concrete Beams by Adopting Gene Expression Programming. Materials, 2022, 15, 3758.

[11] ACI 318-19: Building code requirements for structural concrete, American Concrete Institute, Farmington Hills, America, 2019, 436-449.

[12] Deifalla, A., Awad, A., Seleem, H., Abdelrahman, A., Investigating the behavior of lightweight foamed concrete T-beams under torsion, shear, and flexure. Eng. Struct. 2020, 219, 110741.

[13] Rotaru A., Measurements of bridge structures using non-destructive testing methods and their stability in wind gusts, Reliability: Theory &Applications, 2023, No. 4 (76), 1056-1066.

[14] Jansson A., Lofgren I., Lundgren K., Gylltoft K., Bond of reinforcement in self-compacting steel-fibre-reinforced concrete. Magazine of concrete research, 2012, Volume 64 (7), 617-630.

[15] Kouche, El., Hassanein, H.S., Ultrasonic non-destructive testing using wireless sensor networks. Procedia Computer Science, 10, 136-143.

[16] Sanayei, M., Phelps, J.E., Sipple, J.D., Bell, E.S., Brenner, B.R., Instrumentation, nondestructive testing, and finite-element model updating for bridge evaluation using strain measurements, Journal of bridge engineering, 17(1), 2011, 130-138.

[17] Teplý, B., Keršner, Z., Rovnaník, P. and Chromá, M., Durability vs. Reliability of RC structures. Durability of Building Materials and Components, 2005, 17-20.

[18] Balaji Rao, K., Anoop, M.B., Lakshmanan, N., Gopalakrishnan, S. and Appa Rao, T.V.S.R., Risk-based remaining life assessment of corrosion affected reinforced concrete structural members, 2004.

[19] Odriozola, M.A.B. and Gutiérrez, P.A., Comparative study of different test methods for reinforced concrete durability assessment in marine environment. Materials and Structures, 41(3), 2008, 527-541.

[20] Mehta, P.K. and Gerwick, B.C., Concrete in service of modern world. Dundee, Scotland, UK: Univ. of Dundee, 1996, 1-28.

[21] Lang, Ch., Willmes, M., Non-destructive testing of reinforced concrete structures, Germany, 2018.

[22] Petrakov A.N., Bukin A.V., (2010), Determination of concrete strength by destructive and non-destructive testing methods, No. 1, 89-94.

[23] Rotaru A., Determination of strength characteristics of materials of vertical load-bearing structures, in the collection: Potential of sustainable innovative development: concepts, models and practical application. Collection of articles on the results of the International Scientific and Practical Conference, 2024, 112-114.

[24] Rotaru A., Dynamic load assessment of building structures, E3S Wed of Conferences, 2023, T. 402, 07015.