SOI: 1.1/TAS DOI: 10.15863/TAS
International Scientific Journal
Theoretical & Applied Science
p-ISSN: 2308-4944 (print) e-ISSN: 2409-0085 (online)
Year: 2023 Issue: 04 Volume: 120
Published: 27.04.2023 http://T-Science.org

Issue Article

Denis Chemezov
Vladimir Industrial College
M.Sc.Eng., Academician of International Academy of Theoretical and Applied Sciences, Lecturer,
Russian Federation
https://orcid.org/0000-0002-2747-552X
vic-science@yandex.ru

Egor Prozorov
Vladimir Industrial College
Student, Russian Federation

Semyon Galaktionov
Vladimir Industrial College
Student, Russian Federation

Vladislav Gonchar
Vladimir Industrial College
Student, Russian Federation

Ivan Chebryakov
Vladimir Industrial College
Student, Russian Federation

Mikhail Chebotaryov
Vladimir Industrial College
Student, Russian Federation

Egor Tuykin
Vladimir Industrial College
Student, Russian Federation

ANALYSIS OF CRACK RESISTANCE OF SOME MATERIALS UNDER THREE-POINT FLEXURAL TEST CONDITIONS

Abstract: *The three-point flexural test process was simulated to analyze the crack resistance of plastic mineral mixture (brick), concrete, gray cast iron and S7 tool steel. Damage to deformed samples from plastic mineral mixture and concrete is almost the same in intensity and volume and is observed in the direction of the bend line. Metallic samples are characterized by the greatest deflection at the site of the load and a lower intensity of damage, which does not lead to complete destruction of material. S7 tool steel has the greatest crack resistance.*

Key words: *three-point flexural test, sample, damage, crack, deflection, load.*
Language: *English*
Citation: Chemezov, D., et al. (2023). Analysis of crack resistance of some materials under three-point flexural test conditions. *ISJ Theoretical & Applied Science, 04 (120)*, 278-281.
Soi: http://s-o-i.org/1.1/TAS-04-120-53 ***Doi***: crossref https://dx.doi.org/10.15863/TAS.2023.04.120.53
Scopus ASCC: *2211.*

Introduction

The three-point flexural test is a procedure for loading a prepared sample on special equipment to determine the value of elastic modulus during bending, bending stress, bending deformation, the reaction of material to bending stress and fracture toughness [1]. Concrete, gray cast iron, ceramics, tool steel and other materials are subjected to three-point flexural test. The mechanics of destruction of these materials after the three-point flexural test was investigated experimentally in the works [2-10].

In laboratory conditions, the three-point flexural test is carried out on the universal testing machine when a variable load is applied to the surface of the sample which free from fixation. Deformation (bending) of material is possible by basing the sample on two supporting pins located at a given distance from each other. The study of fracture toughness occurs during cyclic loading of the sample with a notch with measurement of the length of resulting crack.

However, real three-point flexural tests cannot always be implemented due to limitations in the preparation of the technological process (production and quality of samples, duration of the process, etc.). In this case, the use of software products for engineering analysis makes it possible to eliminate these shortcomings of laboratory tests. By specifying various functions in the dialog boxes of specialized Comsol Multiphysics software modules, it is possible to simulate the three-point flexural test process of samples made of various materials presented in the material library or to create a material with the necessary properties. Thus, it is possible to carry out the three-point flexural test without the use of laboratory equipment and physical samples in a short time. The tools of post-processor visualization of the results allow us to make a full-fledged analysis of the mechanical properties and mechanics of fracture (crack formation) of deformed samples.

Thus, in this article, the mechanics of destruction of four materials under the conditions of the simulated three-point flexural test will be demonstrated for the comparative analysis.

Materials and methods

The three-point flexural test of rectangular shaped samples was carried out in the Comsol Multiphysics software. The rectangle model on the plane was mounted on supporting pins and a variable load was applied to the opposite face by an indenter. The load was applied until cracks formed, leading to the subsequent destruction of the sample model. The following metallic and non-metallic materials were examined: plastic mineral mixture, concrete, gray cast iron and S7 tool steel. The material properties of the sample models are presented in the Table 1.

Table 1. Material properties.

Parameter	Material			
	Plastic mineral mixture	*Concrete*	*Grey cast iron*	*S7 tool steel*
Density, kg/m³	2000	2300	7000	7833
Young's modulus, Pa	17×10^9	25×10^9	140×10^9	207×10^9
Poisson's ratio	0.2	0.2	0.25	0.29
Tensile strength, Pa	3500000	3500000	300000000	670000000

The volume of the sample model, which is most subject to deformation, had a fine grid of finite elements to obtain more accurate calculation results. The loading time of all models of samples was 2 s.

Results and discussion

The simulation results are presented in the Fig. 1. The figure on the left shows deformed samples after loading. The color contours indicate the volumes of material that have been damaged during bending. The color of the contour characterizes the intensity of damage: blue is the minimum and red is the maximum. The figure on the right shows the dependencies of deflections of samples on the applied load.

The nature of deformation and damage of samples from plastic mineral mixture and concrete is almost the same. Intense damage to materials is observed along the bending line of the sample. The volume of material indicated in red is the volume damaged by 100%. It is assumed that these samples will be destroyed along the line of action of the load. The greatest strain is 0.06. Differences in the applied loads and deflection values of samples were also noted. The calculated values of the applied load on the sample obtained by the implicit gradient are greater by 1.0 kN than by the crack band. The process of applying the load when calculating the implicit gradient lasted 0.5 s less, so the deflection values of samples differ. The von Mises stress of these materials has both positive and negative values.

The intensity of deformation and damage of metal samples is almost the same. The distribution of damage in the sample made of gray cast iron occurs by about 25% of the total volume. This is twice as much as that of the sample made of S7 tool steel. Damage to materials after application of the load is 27%. There are practically no discrepancies in the calculated values of deflection of metallic samples. The formation of cracks in samples made of gray cast iron and S7 tool steel occurs at 525-740 kN and 730-1000 kN, respectively.

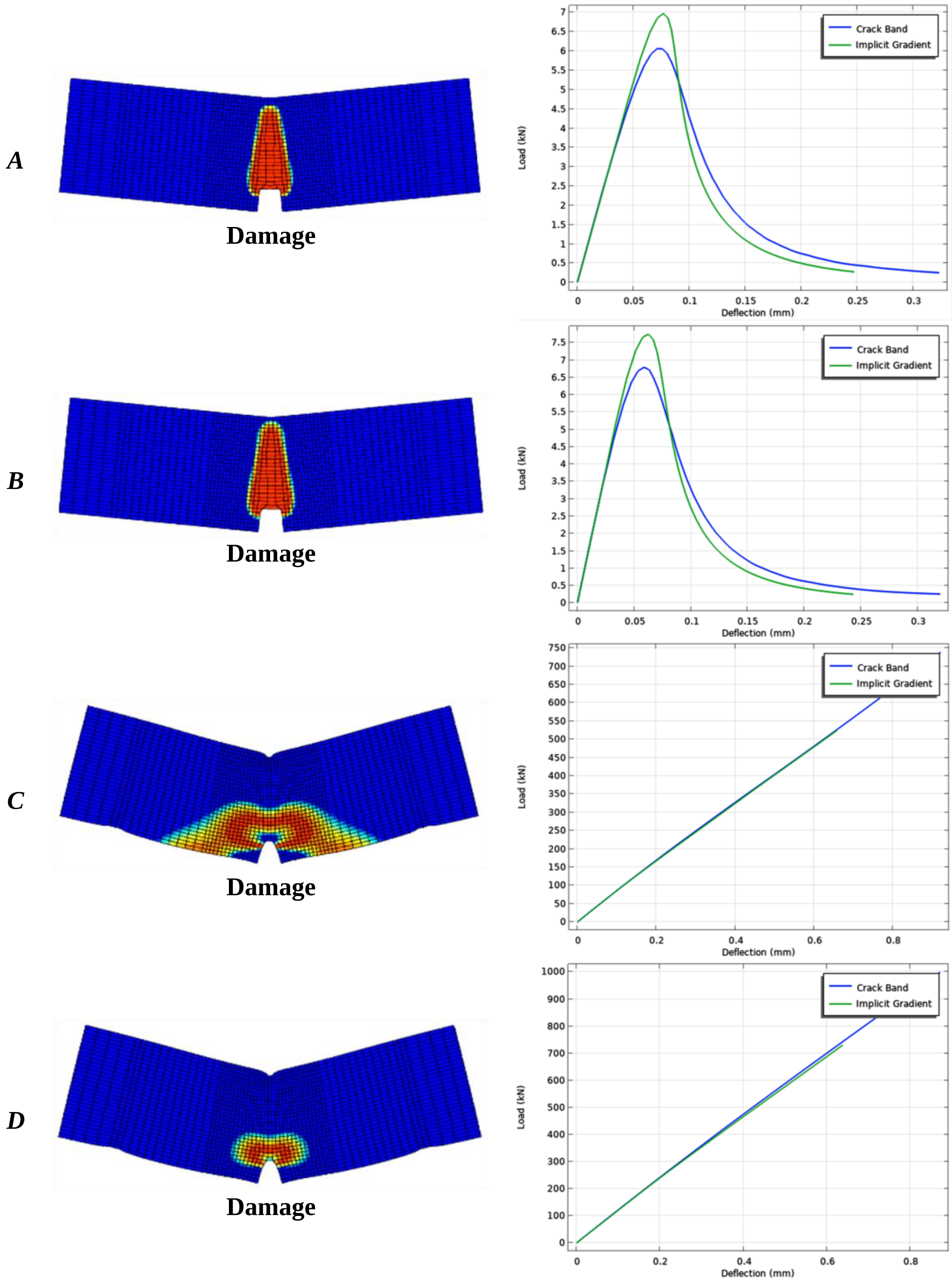

Figure 1 – Contours of damage to samples during bending and the dependencies of deflection of the sample on the applied load: plastic mineral mixture (*A*); concrete (*B*); grey cast iron (*C*); S7 tool steel (*D*).

Conclusion

The three-point flexural test and the comparison of the destruction nature of the sample in the deformed state were performed for four materials. Under bending load conditions, samples made of plastic mineral mixture and concrete have lower strength and are subject to fracture along the action line of the load. Negative values of the von Mises stress calculated for these materials indicate cyclic loading of studied samples. Samples made of metallic materials may be subjected to higher loads. The deflection value of metallic samples before destruction is 2.5 times greater than the deflection value of samples made of plastic mineral mixture and concrete. However, such a deformed state of metallic samples does not lead to complete destruction of material in the loaded zone. S7 tool steel has the greatest crack resistance.

References:

1. (2016). *ISO 7438:2016. Metallic materials - Bend test*.
2. Bocca, P., Carpinteri, A., & Valente, S. (1989). Fracture mechanics of brick masonry: size effects and snap-back analysis. *Materials and Structures, 22*, 364-373.
3. Bernat, E., et al. (2013). Experimental and numerical analysis of bending–buckling mixed failure of brickwork walls. *Construction and Building Materials, 43*, 1-13.
4. Sinha, B., Ng, C., & Pedreschi, R. (1997). Failure criterion and behavior of brickwork in biaxial bending. *J Mater Civil Eng, 9*, 70-75.
5. Srivastava, A. K., Gupta, V. K., Shrivastava, A., & Narain, V. (2017). The bending test on Beam of Aluminium alloy, Gray cast iron, Stainless steel and Structural steel using Ansys Workbench 15. *International Journal of Advanced Research in Science, Engineering and Technology, Vol. 4, Issue 4*, 3831-3839.
6. Kaplan, F. M. (1961). Crack propagation and fracture of concrete. *Journal of the American of Concrete Institute, 58(5)*, 591-610.
7. Cao, H., Zheng, X., Hua, J. M., & Hu, Z. M. (2014). Damage Detection of Prestressed Concrete Beams Based on Nonlinear Dynamic Characteristics. *Engineering Mechanics, 31(2)*, 190-194.
8. Xiang, Q., Cheng, X., Su, J., & Ma, L. (2020). Bending behaviour experiment of a prestressed concrete beam with metal bellows. *Australian Journal of Structural Engineering, 21:4*, 279-293.
9. Limongelli, M. G., et al. (2016). Damage Detection in a Post Tensioned Concrete Beam-Experimental Investigation. *Engineering Structures, 128*, 15-25.
10. Dylewski, A., & Łogin, W. (2018). Simulation of Three-Point Bending of a Simple Composite Beam Using the Commercial FEM Software. *Computational Technologies in Engineering*, 1-8.