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

Irina Pavlukhina
Vladimir Industrial College
Lecturer, Russian Federation

Oleg Stepanov
Vladimir Industrial College
Student, Russian Federation

Danil Zubatov
Vladimir Industrial College
Student, Russian Federation

Maksim Tarasov
Vladimir Industrial College
Student, Russian Federation

DAMAGE ANALYSIS OF CONCRETE

Abstract: *The results of the computer simulation of compression of specimens made of various grades of concrete are presented in the article. The comparison of the damage degree of materials during shortening of the specimens by 10%, 25% and 50% of the initial height was performed.*

Key words: *the compression test, the specimen, concrete, damage, deformation.*
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Introduction

Concrete is main building material. Concrete must have certain physical and mechanical properties, the most important of which are density and strength [1-3]. Since concrete is brittle material, the greatest strength is provided during compression [4-9]. Determination of the strength of brittle material, using the example of the compression test of the round specimens made of gray cast iron, was described in the work [10]. Shortening of the sample during compression by 20% of the initial height led to the formation of extensive cracks by the diameter. Further application of the variable load will lead to the specimen destruction. The advanced functionality of some computer programs allows you to determine the formation of cracks in the specimen during compression deformation based on the calculated values of the material damage coefficient. Thus, it is possible to compare the properties of different grades of concrete and express the strength of materials in terms of the damage coefficient.

Materials and methods

The computer calculation of the compression process of the specimens models made of concrete with the compressive strength of up to 35 MPa and up to 140 MPa was implemented in the ANSYS Autodyn 14.5 program. The specimens models were cylinders with the diameter of 4 mm and the height of 4.5 mm. Each specimen was subjected to the variable load applied to the end surface of the model, which was free from fixing. The properties of the specimens materials are presented in the table 1.

Table 1. The properties of the specimens materials.

Parameter	Concrete (compressive strength is 35 MPa)	Concrete (compressive strength is 140 MPa)
Reference density	2.75 g/cm^3	
EOS		
Equation	*P* alpha	
Porous density	2.314 g/cm^3	2.52 g/cm^3
Porous sound speed	2.92×10^3 m/s	3.242×10^3 m/s
Initial compaction pressure	2.33×10^4 kPa	9.33×10^4 kPa
Solid compaction pressure	6.0×10^6 kPa	
Compaction exponent	3.0	
Solid EOS	Polynomial	
Bulk modulus $A1$	3.527×10^7 kPa	
Parameter $A2$	3.958×10^7 kPa	
Parameter $A3$	9.04×10^6 kPa	
Parameter $B0$	1.22	
Parameter $B1$	1.22	
Parameter $T1$	3.527×10^7 kPa	
Reference temperature	300 K	
Specific heat	654.0 J/(kg×K)	
Compaction curve	Standard	
Strength		
Equation	*RHT* concrete	
Shear modulus	1.67×10^7 kPa	2.206×10^7 kPa
Compressive strength (fc)	3.5×10^4 kPa	1.4×10^5 kPa
Tensile strength (ft/fc)	0.1	
Shear strength (fs/fc)	0.18	
Intact failure surface constant A	1.6	
Intact failure surface exponent N	0.61	
Tens./comp. meridian ratio (Q)	0.6805	
Brittle to ductile transition	0.0105	
G (elas.)/(elas.-plas.)	2.0	
Elastic strength/ft	0.7	
Elastic strength/fc	0.53	
Fractured strength constant B	1.6	
Fractured strength exponent M	0.61	
Compressive strain rate exp. alpha	0.032	0.00909
Tensile strain rate exp. delta	0.036	0.0125
Max. fracture strength ratio	1×10^{20}	
Failure		
Equation	*RHT* concrete	
Damage constant, $D1$	0.04	
Damage constant, $D2$	1.0	
Minimum strain to failure	0.01	
Residual shear modulus fraction	0.13	
Tensile failure	Hydro (P_{min})	
Erosion		
Equation	Geometric strain	
Erosion strain	2.0	
Type of geometric strain	Instantaneous	

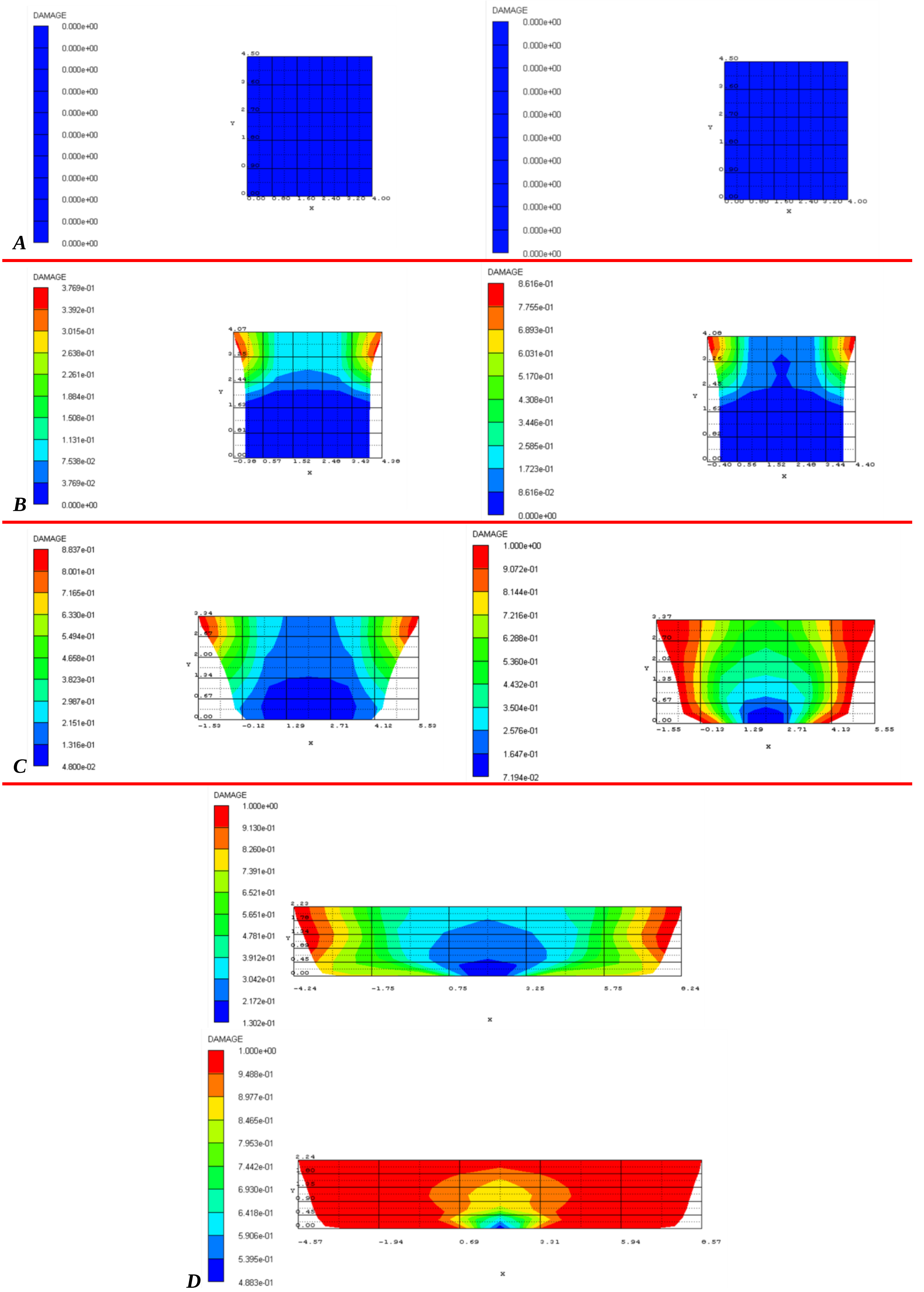

Figure 1 – The damage contours of the specimens during compression: *A* – the specimen before deformation (on the left is concrete with the compressive strength of up to 35 MPa and on the right is concrete with the compressive strength of up to 140 MPa and further); *B* – shortening of the specimen by 10%; *C* – shortening of the specimen by 25%; *D* – shortening of the specimen by 50% (at the top is concrete with the compressive strength of up to 35 MPa and at the bottom is concrete with the compressive strength of up to 140 MPa).

Results and discussion

The results of the computer calculation of the compression process of the round specimens are presented by the color contours of material damage applied to the models surfaces. The color scale placed to the left of the specimens models gives an idea of the damage degree of material during compression. The values indicated to the right of the scale determine the damage degree of material (for example, 1.0 corresponds to 100% damage, 0.5 corresponds to 50% damage, and so on). The coordinate axes plotted on the models reflect the change in the specimens dimensions in the height and the diameter. The damage contours of the concrete specimens during compression are presented in the Fig. 1.

The damage degree of material was recorded during shortening of the specimens models by 10%, 25% and 50% of the initial height.

Shortening of the specimens by 10% is characterized by almost the same distribution of stress in the materials volumes. The maximum value of the material damage coefficient was determined in the volume (2-4%) near the outer diameter of the specimens. High-strength concrete during compression has the value of the damage coefficient 2.3 times greater than concrete with the compressive strength of 35 MPa. The specimens are deformed by 45-50% from the side of the applied load.

Shortening of the specimens by 25% leads to the distribution of stress over the entire volume of material. The increase in the value of the damage coefficient occurs in the material volume from the centerline to the periphery of the specimen. Deformation of high-strength concrete is accompanied by complete damage of the material volume located near the outer diameter of the specimen. The volume of damaged material was 15-20%. Damage of the concrete specimen (the volume not more than 5%) with the lower compressive strength also occurs by the diameter.

Shortening of the model by 50% leads to complete damage of the first specimen by 10% and the second specimen by 70%. The deformed volumes of the specimens models having the values of the damage coefficient of 0.5-0.9 are subjected to the cracks formation.

Conclusion

High-strength concrete is subjected to more extensive damage under the static loads, leading to compression deformation. The specimen is recommended to be compressed by no more than 10% to prevent the cracks formation and subsequent damage of concrete with the compressive strength of 35 MPa. Minimum deformation of material occurs on the centerline of the specimens.

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