Cracks and their role in the life cycle of building materials

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Abstract. Cracks as active elements are presented in all building structures. Cracks define a spontaneous internal restructuring of the structure of the construction material. This is a necessary condition for the adaptation of the system to the influence of unfavorable factors. The presence of active elements in the material of the structure-system contributes to its structural development, which indicates the creative role of cracks. Upon reaching the maximum variety of the structure, cracks-creators are able to develop to cracks of destruction. Cracks-destroyers should be considered as open complex self-organizing systems with their own life cycle. The predominance of the goal of the new crack-system over the goal of the existence of the structure-system leads to the failure of the structure as a basic system. 

Key words: structure-system, structure-forming cracks, destruction cracks, life cycle, structural changes, active elements.

1. Introduction

The life cycle is understood as the period of time of the existence of a structure-system - from the manufacturing and performance of its inherent functions to its withdrawal from the operating mode. This assumes that during this period, a set of interrelated and interdependent processes and stages of structural transformations are implemented, ensuring the safe functioning of the structure. The life story of the system is formed under the influence of the particular life stories of individual structural elements. The structural elements, which by their very presence contribute to the course of the life story of the structure-system, include technological cracks (TC) and internal interface surfaces (IIS).

Cracks and interface surfaces are active structural elements capable of responding in the same tempo-rhythm to external and internal influences and, thus, to participate in the processes of structural “restructuring” of the system, ensuring its external and internal safety [1,2]. Such participation of active elements in spontaneous structural rearrangements should be regarded as the only acceptable one. Otherwise, as a result of similar phenomena of self-organization, active elements can change the life story of the structure-system up to its degradation and death. Therefore, the analysis of the role of cracks as active elements in the life cycle of building structures should be considered an important task.

2. The role of cracks in the destruction of structural material

Failure of structures is associated with the irreversible growth of a crack, which, as a rule, divides the structure into separate parts. Experts note certain stages in the “life” of a crack - from the moment of its initiation and growth to its transformation into a main one with the exit of the crack front to the surface of a specimen or structure. The specific role of a crack is its ability to concentrate the arising deformations and stresses at its mouth, which greatly facilitates the process of its growth in the material environment. Methods for the quantitative assessment of the fracture toughness (fracture
toughness) of a material by determining the stress concentration factors are proposed. Measures have been developed to improve the crack resistance of various materials, including construction materials. Attempts have been made to use critical stress intensity factors in assessing the durability of building materials and in calculating structures. The data presented are quite convincing evidence of a crack as the main factor determining the destruction of materials and structures made of them.

Our analysis showed the inevitability of the appearance of cracks at various levels of structural inhomogeneities for polystructural materials and made it possible to assess the role of cracks in its structural development as elements capable of stabilizing the properties of a structure and thereby ensuring its functionality. In addition, it is shown that the presence of cracks causes a permanent nonequilibrium state of individual subsystems and the system as a whole, and this contributes to the structural development of the system, an increase in its structural diversity and, as a result, a transition to a more equilibrium and stable state. This made it possible to draw a conclusion about the creative role of cracks in the structural development of open complex dynamic systems, which include building structures. There is no alternative to the cause of the destruction of structures as through the irreversible development of cracks. Therefore, the task was determined to study the conditions for the transition from cracks that play a creative role to cracks that cause the destruction of composite building materials and structures.

For the analysis, one should consider the full cycle of the structure's existence, including the active phase of its functioning as an open complex dynamic system.

Due to the fact that cracks as active structural elements of each subsystem and system are included in the model of the structural material and they play an essential role both in the processes of reorganization of the structure in order to stabilize the properties of the system and in irreversible processes of destruction, the main attention in the life cycle of the structure is given to cracks.

The main periods of the life of a structure as a system and the processes that occur at each stage of its existence are presented in table 1.
Table 1

| № | Stages of the system's existence | The main processes characteristic of each stage of the life of the system |
|---|---------------------------------|-----------------------------------------------------------------------|
| 1 | The origin and formation of the system | Initial structure (product geometry; distribution of aggregates, cement, water) ↓ Complex of physical-chemical and physical and mechanical phenomena and processes ↓ Organization of the structure of various levels of structural heterogeneities ↓ Manifestation of equifinality effects ↓ Technological cracks |
| 2 | System operation | Technological cracks ↓ Cracks-relaxers; Cracks-triggers; Cracks-transducers of the structure; Cracks-dissipators ↓ Structural changes (increased degree of structural diversity) ↓ Ultimate structural changes ↓ Nucleation of fracture cracks - trunk cracks |
| 3 | System death | Trunk cracks ↓ Irreversible growth of the trunk crack ↓ Destruction of a structure as a system |

The origin and development of technological cracks in the structure of the material occurs at the stage of the birth and formation of the system. In this case, various mechanisms for organizing the structure of each level of inhomogeneities lead to one result - the appearance of technological cracks. The number and orientation of the initial cracks of various subsystems and the entire system is determined by the initial composition and intensity of the occurrence of physical-chemical and physical-mechanical phenomena and processes that are involved in organizing the structure of the material. The beginning of the system's functioning should be considered as the end of the period of its formation. The structure enters the working life cycle with a certain set of technological cracks at all levels of structural inhomogeneities.

During the period of operation, the material of the structure perceives the entire complex of operational loads, to which active elements react first of all. At this time, the following properties of "cracks-creators" are manifested: - relaxation of deformations and stresses in the material adjacent to the crack edges (cracks-relaxers); - the formation of new areas of the coastal surface, which contributes to the inclusion in the work of metastable elements (trigger cracks); - transformation of cracks into internal interfaces and vice versa, which leads to the formation of new structural elements - blocks (cracks-transducers of the structure); - dissipation of excess energy through the formation of new surfaces (dissipator cracks).

It should be noted that these properties are not possessed by individual cracks. Each crack, depending on the specific situation, exhibits one or another property. This reveals the creative role of
cracks at each level of inhomogeneities (subsystems) and in the entire system. Constant restructuring is taking place, which contributes to increasing the diversity of structure in hierarchical systems. According to R. Ashby's figurative expression, only diversity can destroy diversity. However, in our opinion, the change in structural diversity in order to maintain the required parameters of properties has its limits.

In a functioning system, it can happen that the "cracks-creators" degenerate into "cracks-destroyers", which is a harbinger of a decrease in the properties parameters and the beginning of the period of the system's death. A situation arises in the system in which one of the structure elements takes on the function of the system in which it arose. He closes the goal of creating and the existence of the system on himself. Such a structural element primarily perceives the entire range of operational loads, which contributes to its own growth. With a size comparable to the size of individual subsystems (structural inhomogeneities), he no longer "feels" their structural features. This drastically reduces the structural diversity of the system. The processes that inevitably take place in separate subsystems, structural blocks, etc. are insignificant for the dominant structural element. Such a structural element, in our case a fracture crack, itself becomes a system that can be regarded as an open complex dynamic system.

Openness assumes that the crack, with its elements, is capable of perceiving, transmitting and redistributing deformations and stresses in the environment - the original system. The complexity in this case is associated not only with the complex structure of the crack itself, but also with its rather complex behavior. Being an unstable system itself, a fracture crack, reacting to external influences, is capable of stopping, bending the outlines of the front, absorbing other cracks, and responding to local and integral fields of residual deformations.

The dynamism of a crack as a system assumes that each subsequent state is determined by the previous one. In this case, the new state may differ from the previous one in many parameters and indicators. This presupposes the irreversibility of the development of a dynamic crack-system in the process of reaching the target setting.

The target setting of the resulting system, for which the original system becomes a subsystem, is to ensure a complete life cycle.

A crack as a system goes through the full path of its "life" - birth, active functioning and death. The death of a crack as a system occurs when its main attributes - the mouth and front - disappear. In our opinion, the difference between “cracks-destroyers” and “cracks-creators” lies in the fact that the death of the former is associated with the disappearance of the front when it reaches the surface of a sample of a product, structure, etc. The death of "cracks-creators" occurs when their front reaches the banks of other cracks and interfaces. In this case, it is not so much the death of the "cracks-creators" that occurs, but their spontaneous transformation into a qualitatively different structural element - the inner interface.

During the period of active life, in order to ensure the priority of its own development, the fracture crack as a system uses all the potential capabilities of the base system and its structural features. The characteristic features of the "crack-system" that have arisen include: - the size (volume), which includes several subsystems of the base system and thus turns it into an independent extremely unstable system; - the ability to "draw" into itself on the way of its own growth other active elements of the structure (the multiplicity of attractors gives rise to the emergence of one attractor); - the ability of directed concentration of energy in the zones of its development, which practically excludes the influence of the structural diversity of the basic system on the growth conditions of the new system.

Upon reaching a certain stage of growth, the new system is capable of developing irreversibly using its own resources. It begins to exist at its own pace, striving to complete its development. This leads to the death of two systems at once - the new system due to the achievement of the goal of its existence and the basic system due to the fact that the new system, having died, led to the loss of its main functions. This completes the life of the original system due to the completion of the growth of the fracture crack.
3. Conclusion
The studies carried out allow us to draw the following conclusions:
Fracture crack should be considered as an open complex dynamic system. The purpose of the existence of such system is its own development. The appearance of fracture cracks (main cracks) simplifies the structural design of the base system. The activity of the new system presupposes that the goals of the new system prevail over the goal of the functioning of the original system. Achieving the goal of crack development as a system leads to its death and to the completion of the life cycle of the structure as a system.

References
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