Deformation Dependencies of the Power and Environmental Resistance of Reinforced Concrete Structures Under Accidental Actions

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Abstract. The problem of determining the parameters of the stress-strain state of reinforced concrete bending elements with the simultaneous manifestation of force loading and environmental impact under static-dynamic loading conditions is considered. Dependences of the deformation model were constructed using the integral modulus of deformations by V M Bondarenko. The parameters of the diagrams of the static-dynamic deformation of the section of corroded concrete under the action of a static and short-term dynamic load are determined on the basis of a rheological two-element model of concrete deformation of the theory of plasticity by G A Genieva. At the same time, the hypothesis was accepted that the relationship between stresses and strains in corrosion damaged concrete under its short-term loading is affinity-like to similar dependencies of undamaged concrete, and the ultimate deformations of concrete under static and static-dynamic loading modes are equal to each other. A methodology and an algorithm for the computational analysis of the strength and environmental resistance of reinforced concrete structures at all stages of static-dynamic deformation are proposed.

1. Introduction

During operation, about 75% of building structures in the world are subject to destructive environmental influences, at the same time it is necessary to take into account accidental actions, including emergency ones. One of the important components in solving the problem of the structural safety of buildings and structures is the most complete accounting of their operational wear and damage, and, as a consequence, the assessment of the power and environmental resistance of such building structures. The development of such a conceptual and methodological approach to solving problems of the structural safety of structures is associated with the use of modern deformation models of the strength and environmental resistance of reinforced concrete in relation to such problems. The emergence of such problems requires the use of new parameters of the deformation diagrams of reinforced concrete sections under its regime static-dynamic loading. In this direction, in the country and abroad, certain results of experimental and theoretical research have been accumulated, among them the research of V M Bondarenko [1], G A Genieva [2], N I Karpenko [3], V O Almazov [4], Vl I
Kolchunova [5], R S Sanzharovsky [6], B S Sokolova [7], G A Smolyago [8], A I Popesco [9], X Lu [10], B R Ellingwood [11], N V Fedorova [12], V I Travusha [13], A G. Tamrazyan [14], Diagoro I [15], Ibragim M H Alshaikh [16] and others.

There is no doubt that the finite element method (FEM) is a fairly effective method for solving nonlinear problems of structural mechanics of reinforced concrete and is widely used in the practice of scientific research and design of reinforced concrete structures. At the same time, the experience of researching reinforced concrete structures (works of S F Klovanich [17], Yu V Veruzhsky, Vl I Kolchunov [18], N I Karpenko, A N Petrov [19], A S Gorodetsky [20], Z P Bazant [21] and others) revealed certain difficulties when using FEM in nonlinear calculations of reinforced concrete structures. In a step-by-step calculation procedure, the convergence of the process deteriorates with an increase in the stress-strain state in structures. This is a consequence of the development of cracks and the manifestation of nonlinear properties of concrete and reinforcement, even under short duration loads. At high load levels, a simple iterative process converges poorly; a discrete change in the stiffness of finite elements is manifested, they do not take into account the transfer of shear through the crack, the engagement of its edges and other specific features of reinforced concrete.

When concrete creep is taken into account, the efficiency of using FEM in reinforced concrete problems is further reduced. The theory of reinforced concrete in the future should use all the advantages of the finite element method, and the latter operates with rationally selected data structures that can be automatically generated from a database on the physical and mechanical properties of structures and their geometry. Therefore, at present, when assessing the strength resistance of reinforced concrete structures, especially those with complex stress, they increasingly often focus on the use of low-iteration or non-iteration calculation algorithms.

Special calculation and mathematical models of nonlinear deformation of reinforced concrete are designed to form a toolkit for describing various types of stress states. One of the elements of such a toolkit is such an important parameter as the integral modulus of concrete deformations [2], on the basis of which a wide range of problems in the theory of reinforced concrete can be solved.

In this work, on the basis of the integral deformation module, deformation dependences are constructed for analyzing the force and environmental resistance of reinforced concrete structures under special influences.

2. Deformation integral module method of the reinforced concrete theory

Under the action of a static load, various points along the height of the section of an element experiencing an inhomogeneous stress-strain state have different stresses. In this case, the nonlinearity and heterogeneity of the material deformation predetermines the difference in the deformation modulus at points with different stresses. Operating with different deformations modulus at each point with a non-uniform stress state in the section of a reinforced concrete element, especially with a complex stress state, leads to complex multi-iteration algorithms and, accordingly, increases the time for solving nonlinear problems of calculating reinforced concrete structures. This task is even more complicated in the case of the simultaneous manifestation of force and environmental impact.

Therefore, one of the ways to solve such problems is to create deformation dependencies and calculation models based on analytical tools and, in particular, an equivalent deformation modulus, which integrally takes into account the stress section level, loading mode and reflects the nonlinearity and nonequilibrium of physical processes of deformation of the section of a reinforced concrete element. The idea of creating such models was expressed by Professor V M Bondarenko as a generalization of his proposed deformation integral module [22, 23]. The rheological equation of material deformation $\varepsilon(t_0)$, reflecting nonlinearity, nonequilibrium and other features of deformation, in the general case, can be represented by the dependence (Figure 1):

$$\varepsilon^{ln}(z, t, t_0) = \frac{\sigma(u, z, t)}{E^{ln}(u, t)}, \quad (1)$$
where $E_{in}(v,t)$ is the required integral modulus of deformations for a section with an abscissa $v$ of the section along the span (the $v$ axis is directed along the bar); $z$ is the ordinate of the fiber along the section height.

The introduction of a total deformation modulus into consideration leads to the inequality for the most points of the section:

$$\Delta \varepsilon = \varepsilon[\sigma(z,t), t, t_0] - \varepsilon_{in}[\sigma(z,t), t, t_0] \neq 0. \quad (2)$$

Inequality (2) inevitably follows from the replacement of the discrete deformation modulus at each point of the inhomogeneously stressed section with a total integral modulus. To minimize the deviation $\Delta \varepsilon$ not for each point separately, but for the section as a whole, the integral minimization of the deviation $\Delta \varepsilon$ can be used. For greater accuracy, the minimization of the quadratic $m$-moment deviation $\Delta \varepsilon$ is carried out with respect to the desired $1/E_{in}$. After integration and some simplifications, the expression for the integral deformation modulus is represented as:

$$E_{in}(v,t) = \frac{\int_{p}^{q} \sigma(z,t) \varepsilon(z,t) dz}{\int_{p}^{q} \varepsilon(z,t) dz}, \quad (3)$$

where $b(z)$ is the width of the reinforced concrete element section ($b(z) = \text{const}$ for rectangular sections);

$m$ - degree of deviation moment $\Delta \varepsilon$, determined from additional conditions;

$p$ and $q$ are the limits of integral minimization over the section height;

$z$ is the distance from the neutral axis of the section along the stress diagram to the point under consideration.

Expression (3) for the integral deformation modulus depends on the stress state level of the sections at each point ($\sigma$) and reflects the selected material rheological equation $\varepsilon(t, t_0)$.

Figure 1. To the calculation of the integral deformation modulus of a reinforced concrete bending element.

3. Initial hypotheses
To construct integral deformation relationships describing the power and environmental resistance simultaneous manifestation of reinforced concrete structures under static–dynamic loading, the following hypotheses and assumptions were adopted.

- The deformation compatibility condition of concrete and reinforcement at points of the bond surface at the same values of the ordinate $z$:

$$\varepsilon_s = \varepsilon_b, \varepsilon''_s = \varepsilon''_b. \quad (4)$$
The law of deformation changes along the section height is described by the relationship [22]:

\[ \varepsilon = \left( \pm \frac{a_0 + z}{x} \right)^n \varepsilon_f. \]  

(5)

where \( \varepsilon_f \) is the extreme fiber deformation;

\( a_0 \) - zero line displacement of the deformation diagram with respect to the stress diagram neutral axis ("+" sign - the height of the compressive normal stress diagram decreases with time; "-" sign - when the latter increases);

\( n \) is the warping coefficient of the section (determined depending on the section position between the cracks and the action of transverse forces);

\( x \) - the height of the compressed zone of the element normal section.

The assumption about flat sections (about straight normals), warping for non-thin-walled sections can be neglected (\( n = 1 \)), then expression (5) will take the form:

\[ \varepsilon = \frac{\pm a_0 + z}{x} \varepsilon_f. \]  

(6)

Affine similarity of the deformation diagrams and normal stresses in the element cross section, that is, the law of normal stresses variation along the section height in accordance with the assumption of the transfer validity of the "stress-strain" diagram, it is allowed to use the dependence:

\[ \sigma_b = \left( \frac{z}{x} \right)^n \sigma_{b,f}. \]  

(7)

where \( n \) is the normal stress nonlinearity parameter (\( 0 \leq n \leq 1 \)).

Changes in the strength of loaded and corrosively damaged concrete over time, simultaneously taking into account the process of increasing the healthy concrete strength (theory of concrete aging), and the process of the aggressive environment effect on concrete, is described using the deformation model of G A Geniev [24,25] with the following dependence:

\[ R_b(t, \tau) = R_b^0(\tau) + R_b(t) - R_b(\tau_0). \]  

(8)

where \( R_b^0(\tau) \) is the function of changing the corrosion-damaged concrete compressive strength in time \( \tau \); \( R_b(t) \) is the function of changing the healthy concrete compressive strength in time \( t \); \( R_b(\tau_0) \) - the function of changing the concrete compressive strength over time until the moment of exposure to an aggressive environment.

The level of stress state, mode and duration of corrosively damaged concrete loading structure is described by the diagram "\( \sigma \)-\( \varepsilon \)" of static-dynamic deformation of loaded and corrosively damaged concrete (Figure 2).

The relationship between stresses and deformations in corrosively damaged concrete during its short-term loading is affine-like to similar dependencies of undamaged concrete.

Ultimate deformations of concrete under static and dynamic loading conditions are equal to each other [26]:

\[ \varepsilon_{b2} = \varepsilon_{b2}^d. \]  

(9)

The function of damage to concrete by corrosion \( k(z) \) to a depth \( \delta \) is described by a polynomial and is determined from geometric conditions in coordinates \( \upsilon_0z \) (Figure 1) [27]:

\[ k(z) = \sum_{i=0}^{i=2} a_i \cdot z^i. \]  

(10)

\( a_0 = 0, a_1 = 2/\delta, a_2 = \delta^2 \); the height of the compressed zone is determined: \( x = \delta + x^* \).

The function of concrete damage by corrosion \( k(z) \) remains the same for all characteristics of the strength resistance of concrete (equivalence sign) [21]:

\[ k(z) = \frac{R'(z)}{R} = \frac{E'(z)}{E} = \frac{c_0}{c^*(z)} = const. \]  

(11)
Figure 2. General view of the static-dynamic deformation diagram "σ-ε" of loaded and corrosively damaged concrete: 1 - mechanical model of the material for describing the development of long-term deformations associated with the appearance of the creep phenomenon; 2 - material mechanical model for the analytical description of the short-term deformation process of under dynamic action.

4. Deformation model

Integral deformation modulus formula (3) for the compressed zone of a bending element of rectangular section $b(z) = \text{const}$ and boundary conditions $p = 0, q = x$, with the substitution $\varepsilon$ (formula (5)) and $\sigma$ (formula (7)), and also, taking into account the assumption of flat sections ($n_e = 1$), $a_0 \neq 0$, is represented by the expression:

$$E^{in}(u, t) = \frac{\int_0^x \left( \frac{x}{z} \right)^{n_e} \sigma_{b.f} x^{2m} \sigma x \ dx}{\int_0^x \left( \frac{x}{z} \right)^{n_e} \varepsilon_{b.f} x^{2m} \varepsilon x = \frac{1}{1 + 2m + n_e} \frac{a_0}{\varepsilon_f} \frac{\sigma_{b.f}(u, t)}{\varepsilon_f(u, t)}}. \quad (12)$$

When aligning the zero line of the deformation diagram with respect to the neutral axis of the stress diagram $a_0/x \rightarrow 0$, but at the same time $n_e \neq 1$, expression (12) will take the form:

$$E^{in}(u, t) = \frac{\int_0^x \left( \frac{x}{z} \right)^{n_e} \sigma_{b.f} x^{2m} \sigma x \ dx}{\int_0^x \left( \frac{x}{z} \right)^{n_e} \varepsilon_{b.f} x^{2m} \varepsilon x = \frac{1 + 2m + n_e + n_e}{1 + 2m + n_e} \frac{a_0}{\varepsilon_f} \frac{\sigma_{b.f}(u, t)}{\varepsilon_f}}. \quad (13)$$

To determine $\varepsilon_f(u, t)$, we use the rheological equation of concrete deformations proposed by V M Bondarenko and recorded for extreme fiber [20]:

$$\varepsilon_f(t, t_0) = \varepsilon_{sh}(t, t_0) + \int_{t_0}^t S_{cr} \left[ \frac{\sigma(t)}{R(t)} \right] \frac{\partial}{\partial t} C^*(t, t) \ dt. \quad (14)$$

In equation (14), the first term $\varepsilon_{sh}(t, t_0)$ is the relative shrinkage (or swelling) strains accumulated from time $t_0$ to time $t$. If the origin of shrinkage deformations $t_{0,sh}$ does not coincide with the start of loading $t_0$ ($t_{0,sh} \neq t_0$), then $t_0$ must be replaced by $t_{0,sh}$. Shrinkage (or swelling) deformations do not depend on the applied stresses.
The second term in equation (14) \( \varepsilon_{b1}(t) = \frac{5 \nu b \int [\varepsilon(t)]}{\varepsilon_{b1}(t)} \) are the relative elastic-instantaneous deformations of concrete at the time of observation \( t \), is determined only by the magnitude of the stresses at this moment and the modulus of the concrete deformations of the same name, the age of which coincides with the moment of observation, but does not depend on the magnitude, duration and mode of the previous loading.

The third term in equation (14) \( \varepsilon_{cr}(t, t_0) = \int_{t_0}^{t} s_{cr} \left[ \frac{\varepsilon(t)}{R(\varepsilon)} \right] \frac{d}{dt} C^*(t, \tau) d\tau \) - relative creep deformations accumulated from the moment of time \( t_0 \) to the moment of observation \( t \) at any mode of monotonic loading (reflects the phenomenon of heredity) and age-related changes in concrete. At the moment of loading, the creep deformations are equal to zero: \( C^*(t, t_0) = 0 \) at \( t = t_0 \).

In the case of a static-dynamic loading mode, appropriate changes must be made to the general formula for the deformation integral modulus and the parameters included in equation (13) with the simultaneous power and environmental resistance of a rectangular section reinforced concrete bending element. Taking into account the duration of power loading and the development of long-term deformations at all stages of the static-dynamic loading regime by determining the corresponding terms \( \varepsilon_{f}(v, t) \) (formula (14)).

Let us consider the linear static section "O-F" of the static-dynamic deformation diagram "\( \sigma-\varepsilon \)" of loaded and corrosively damaged concrete (see figure 2). At the initial moment of time \( t_0 \), it is assumed that zero stresses and zero deformations are combined on a single neutral axis (figure 3). Taking into account the hypothesis of flat sections \( (n_\sigma = 1) \) and the linear formulation of the deformation problem \( (f_0 = 0, n_\sigma = 1) \), the integral modulus (13) can be represented by the dependence:

\[
E^{in}(v, t_0) = z^{(1+m)+1} \frac{\sigma_{bf}(v, t)}{1+2z(m+1)} \frac{\varepsilon_{f}(v, t)}{\varepsilon_{f}(v, t)} = E_{fr}(v, t),
\]

(15)

where \( \sigma_{bf}(v, t) \) is the fiber stress of the \( z_i \) concrete layer;
\( \varepsilon_{f}(v, t) \) - fiber deformations of the \( z_i \) concrete layer;
\( E_{fr}(v, t) \) - deformation temporary modulus.

Determination of parameters \( x^* \) and \( \sigma_{bf} \) included in dependence (15) on the section of the diagram "O-F".
1) Based on the law of deformation variation along the section height (formula (5)), and the conditions for compatibility of deformations (formula (4)), the relationship between the relative deformations of reinforcement and concrete can be written as follows:

\[ \varepsilon_s' = \left( \frac{x-a}{x} \right)^n \cdot \varepsilon_{b,f}' \quad \varepsilon_s = \left( \frac{h_0-x}{x} \right)^n \cdot \varepsilon_{b,f}. \] (16)

2) The stresses in compressed and tensile reinforcement are determined by the expressions:

\[ \sigma_s' = \varepsilon_s' \cdot E_s; \quad \sigma_s = \varepsilon_s \cdot E_s. \] (17)

3) Substitute expression (16) into formula (17), we obtain:

\[ \sigma_s' = E_s \left( \frac{x-a}{x} \right)^n \cdot \varepsilon_{b,f}' \quad \sigma_s = E_s \left( \frac{h_0-x}{x} \right)^n \cdot \varepsilon_{b,f}. \] (18)

4) Substituting in formula (18) the deformation modulus for the fiber layer of concrete in the compressed zone, we obtain:

\[ \sigma_s' = \frac{E_s}{E_{b,f}(u,t)} \left( \frac{x-a}{x} \right)^n \cdot \sigma_{b,f}(u,t); \sigma_s = \frac{E_s}{E_{b,f}(u,t)} \left( \frac{h_0-x}{x} \right)^n \cdot \sigma_{b,f}(u,t). \] (19)

5) The condition of equilibrium of all forces in the section on the axis \( \nu \Sigma \nu = 0 \) is written in the form:

\[ z_b' + z_b + z_s' - z_s = 0. \] (20)

Considering that the height of the compressed zone: \( x = \delta + x' \), the forces in compressed corroded concrete and forces in compressed undamaged concrete are taken into account by two terms in equations (20) and (21).

\[ b \int_0^\delta \sigma_{b,f} dz + \frac{2}{3} \cdot b \cdot \delta \cdot \sigma_{b,f} + \frac{b^2 x'}{n_{\sigma+1}} \cdot \sigma_{b,f} + \sigma_s' \cdot A_s - \sigma_s \cdot A_s = 0. \] (21)

\[ \frac{2}{3} \cdot b \cdot \delta \cdot \sigma_{b,f} + \frac{b^2 x'}{n_{\sigma+1}} \cdot \sigma_{b,f} + \sigma_s' \cdot A_s - \sigma_s \cdot A_s = 0. \] (22)

\[ x' = \frac{\left( \sigma_s A_s - \sigma_s A_s - \frac{2}{3} b \cdot \delta \cdot \sigma_{b,f} \right) (n_{\sigma+1})}{b \cdot \sigma_{b,f}}. \] (23)

6) The moments equilibrium condition of all forces (\( \Sigma M_{n,a} = 0 \)) relative to the neutral axis is written as:

\[ b \int_0^\delta \sigma_{b,f} \left( \frac{\delta}{3} + x' \right) dz + b \int_0^\delta \sigma_{b,f} \cdot z \cdot dz + \sigma_s' \cdot A_s \cdot (x - a) + \sigma_s \cdot A_s \cdot (h_0 - x) - M = 0, \] (24)

or

\[ \frac{2}{3} \cdot b \cdot \delta \cdot \sigma_{b,f} \left( \frac{\delta}{3} + x' \right) + b \cdot \frac{(x')^2}{n_{\sigma+2}} \cdot \sigma_{b,f} + \sigma_s' \cdot A_s \cdot (x - a) + \sigma_s \cdot A_s \cdot (h_0 - x) - M = 0, \] (25)

from which the fiber stress \( \sigma_{b,f} \):

\[ \sigma_{b,f} = \frac{M - \sigma_s A_s (x - a) + \sigma_s A_s (h_0 - x)}{\frac{2}{3} b \cdot \delta (\frac{\delta}{3} + x') + \frac{(x')^2}{n_{\sigma+2}}}. \] (26)

Consider a non-linear static section "F-A" ("F-C") of the static-dynamic deformation diagram of loaded and corrosively damaged concrete (see Figure 2). In this calculation, the calculated dependence (12) is used for the deformation integral modulus. In this case, the deformation integral modulus, like the deformation temporary modulus, does not depend on the level of the stress state, but is determined only by the mode and duration of loading.

Determination of the parameters \( x' \) and \( \sigma_{b,f} \) included in dependence (12) on the sections of the diagram F-A and F-C.
1) Based on the deformation law change along the section height (formula (5)), the conditions for deformation compatibility (formula (4)), the relationship between the relative deformations of reinforcement and concrete can be written as follows:

\[ \varepsilon_s = \left( \frac{x-a}{x} \right)^n \cdot \varepsilon_b,f, \quad \varepsilon_s = \left( \frac{h_0-x}{x} \right)^n \cdot \varepsilon_b,f. \]  

(27)

2) Stresses in compressed and tensile reinforcement:

\[ \sigma_s = \varepsilon_s \cdot \sigma_s, \quad \sigma_s = \varepsilon_s \cdot \frac{\beta_s}{\psi_s} \cdot E_s. \]  

(28)

3) Similarly to the previous calculations for \( x \) and \( \sigma_{b,f} \), we obtain with allowance for \( \beta_s \) (parameter of nonlinearity of deformation of tensile reinforcement) and \( \psi_s \).

From the transformed expression of the equilibrium condition for all forces in the section on the axis \( \sum u = 0, x^* \) is determined (where \( x = x^* + \delta \)):

\[ \frac{2}{3} b \cdot \delta \cdot \sigma_{b,f} \left( \frac{\delta}{3} + x^* \right) + b \cdot \left( \delta + x^* \right) \cdot n_{\sigma} \cdot E_{b,f} \cdot (n_{\sigma} + 1) \cdot (x^* + \delta - \alpha') \cdot A_s - \left( n_{\sigma} + 1 \right) \cdot \frac{\beta_s}{\psi_s} \cdot (h_0 - \delta - x^*) \cdot A_s = 0. \]  

(29)

Expression (29) is reduced to a quadratic equation with unknown \( x^* \).

The transformed expression of the equilibrium condition for the moments of all forces (\( \Sigma M_{\text{n.a.}} = 0 \)) relative to the neutral axis is written as:

\[ \frac{2}{3} b \cdot \delta \cdot \sigma_{b,f} \left( \frac{\delta}{3} + x^* \right) + b \cdot \left( \delta + x^* \right) \cdot E_{b,f} \cdot \left( \frac{x^*+\delta-a}{\delta+x^*} \right)^2 \cdot \sigma_{b,f} \cdot A_s + \frac{\beta_s}{\psi_s} \cdot E_{b,f} \cdot \left( \frac{h_0-\delta-x^*}{\delta+x^*} \right)^2 \cdot \sigma_{b,f} \cdot A_s - M = 0. \]  

(30)

From expression (30) it follows:

\[ \sigma_{b,f} = \frac{M}{W}. \]  

(31)

where

\[ W = \frac{2}{3} b \cdot \delta \cdot \left( \frac{\delta}{3} + x^* \right) + b \cdot \left( \delta + x^* \right) \cdot E_{b,f} \cdot \left( \frac{x^*+\delta-a}{\delta+x^*} \right)^2 \cdot A_s + \frac{\beta_s}{\psi_s} \cdot E_{b,f} \cdot \left( \frac{h_0-\delta-x^*}{\delta+x^*} \right)^2 \cdot A_s. \]  

(32)

calculated modulus of section of corrosively damaged reinforced concrete element.

Let us consider the dynamic section "A-B" ("C-D") of the static-dynamic deformation diagram "\( \sigma-\varepsilon \)" (see Figure 2) of loaded and corrosively damaged concrete. In this section, the calculated dependence (12) is used for the integral deformation modulus.

The section of the concrete deformation diagram "A-B" ("C-D") is described by mechanical model 2. With a sudden application of dynamic loading (impact) caused by a sudden redistribution of the force flow in the element under consideration, instantaneous internal viscosity forces of concrete resistance appear, which directly perceive the external impact and inhibit the development of deformations of concrete [24-27].

In this case, the deformation integral modulus is described by expression (12), and the values of the parameters \( x^* \) and \( \sigma_{b,f} \) included in this expression are determined from equations (23) and (26).

A particular case is the limiting state of a normally reinforced section of a reinforced concrete element, when the bending moment (\( M = M_u \), \( n_0 = f_0 \)), the fiber stresses in concrete in the compressed zone are equal to the dynamic compressive strength of concrete in bending (\( \sigma_{b,f} = R_{b} \)), the stresses in tensile and compressed reinforcement are equal to the corresponding ultimate strength (\( \sigma_s = R_s; \psi_s = 1 \)). The parameters \( x \) and \( \sigma_{b,f} \) for this case are determined by the expressions:

\[ x^* = \frac{\left( R_s A_s - \sigma R_{b,f} A_s - \frac{2}{3} b \cdot \delta \cdot R_{b,f} \right) (f_0 + 1)}{b \cdot R_{b,f}^2}. \]  

(33)
5. Conclusions

Calculated dependences of the mode of integral resistance of damaged reinforced concrete elements, taking into account nonlinearity and nonequilibrium, are constructed on the basis of the deformation integral modulus under special loading conditions. A methodology and an algorithm for the computational analysis of the power and environmental resistance of reinforced concrete structures at all stages of static-dynamic deformation are proposed.

On the basis of the deformation integral modulus model, deformation dependences for the parameters of the diagrams of static-dynamic deformation of bending reinforced concrete structures with the simultaneous manifestation of corrosion damage and power regime loading are obtained. The proposed calculation algorithm makes it possible to determine the parameters of nonlinear deformation section diagrams of a reinforced concrete element under the considered influences and loading conditions with a limited number of iterations.

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