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# Deformations and Tension in Concrete of Squeezed Zone of Non-Centrally Loaded Ferroconcrete Elements

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**Abstract:** Results of the experimental studying of deformations with the first application of a method of a holographic interferometry in research of the samples or models of the squeezed ferroconcrete designs are presented. Prototypes, means of their loading and method of registration of holograms are described. A set of the interferometer and the scheme of realization of a method of two expositions in the record of interferograms at a step loading of the studied objects is shown in details. The way of interpretation and results of the analysis of regularities of the interferential strips arrangement is specified. On the basis of data of the experiment it is established that in the method of holographic interferometry by means of only qualitative analysis of a picture of interferential strips it is possible to receive a full picture of distribution of deformations of ferroconcrete element side. The received dependences of deformation of cross sections confirm justice of application of a hypothesis of flat sections in settlement models. Using results of experiments of different researchers, the analysis of characteristics of concrete tension of a squeezed zone of ferroconcrete designs which are reinforced by steel of the S800 class and more on the basis of which it is offered to apply the transformed diagram "tension deformation" to the concrete in the general deformation method of calculation. The diagram considers influences of a gradient of deformations' distribution and high-strength fittings.

**Key words:** Deformation, holographic interferometry, hypothesis of flat sections, the diagram tension deformation, concrete of the squeezed zone, tension characteristics, flexible racks, high-strength fittings

## INTRODUCTION

The general deformation settlement model of sections which are normal to a longitudinal axis of a ferroconcrete element (Andreev, 1982; Batashed, 1978; Basovets, 1999; Beglov *et al*., 2004) is based on acceptance of hypotheses which allow to simplify the solution of problems of calculation of designs due to standardization of initial prerequisites in creation of settlement schemes. One of fundamental hypothesis are the one of flat sections assuming compatibility of deformations of concrete and fittings of ferroconcrete elements and also a hypothesis which accepts distribution diagram of tension distribution in concrete of the squeezed zone of section which is described by curvilinear dependence "tension deformation" received from experiences on samples prisms at a uniform tension. According to this, in calculations of bent and non-centrally loaded elements it is possible to use the diagram of deformation of concrete σ-ε which is received for other conditions: monoaxial, uniform compression. There is a set of offers on the description of diagrams of concrete deformation, in the form of polynoms, power, exponential, fractional and rational functions and other dependences. This or that dependence can be chosen taking into account features of a solved task.

The modern level of development of means and methods of measurements doesn't allow defining experimentally dependence σ-ε in concrete of the squeezed elements of designs with sufficient reliability. However, further studying of nature of deformation and tension of ferroconcrete elements on experimental basis is important in improvement of settlement theories.

## MAIN PART

**Distribution of deformations on height of cross sections of skilled samples models of ferroconcrete elements (method of holographic interferometry):** Methods of strain measurement which are widely used in pilot studies demand attraction of a large number of converters of deformations that increases labor input of

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experiment and reduce accuracy of measurements. The method of holographic interferometry excludes some shortcomings and systematic errors of other methods of strain measurements and to receive information in the form of deformations of a studied object surface, recorded at each stage of development of the deformation process and appearance of cracks. The holographic method is widely applied in various areas of equipment and is in certain cases an effective remedy of researches (Semyonov, 1985; Alexandrovsky, 1982; Popkov and Machkavtssev, 1995).

The problem of this research was experimental studying of deformations' field with application of a holographic method for the first time in research of the squeezed ferroconcrete designs at all stages of deformation. Researches were conducted on six samples with sizes of 50×50×250 mm which were made of fine-grained concrete with reinforcing by S500 wire by diameter of 3 mm.

For strengthening of basic sections, samples at production were equipped with steel plates. For the purpose of ensuring anchoring of fittings both of its ends were removed through openings out of limits of steel face plates and welded. Production and test of three types of samples (Table 1) was provided. The samples differed by a number of fittings, the provision of the appendix points of longitudinal test loading, so that work cases with "small" and "big" eccentric systems was provided.

As the loading device the TShP-2 hardness gage is used with the extended power racks. Registration of holograms was carried out by the extra bench interferometer, fixed together with a radiator (helium the neon laser) the LG52-2 type on the studied sample (Fig. 1).

Record of the image of a surface of an average site of a samples' lateral side was registered on a flat photosensitive photoplate with sizes of 30×90 mm and resolution not <5000 lines $mm^{-1}$. The direction of illumination of a surface was guided perpendicular to their longitudinal axis. For interpretation of interferograms on a studied surface of sides, a coordinate grid was put previously. Record of holograms was carried out by a method of two expositions. In intervals between expositions, load on a sample increased on 0.05-0.1 from the destroying load. After each step of loading the registered interferogram was shown and was controlled.

On the received sets of interferograms, corresponding to certain stages of loading and types of samples, the analysis of results of researches (Fig. 2) is carried out.

The majority of interferograms contains interferential strips forming a characteristic picture as "a cross", one of which strips is perpendicular to a longitudinal axis of an element and another one is almost parallel to it.

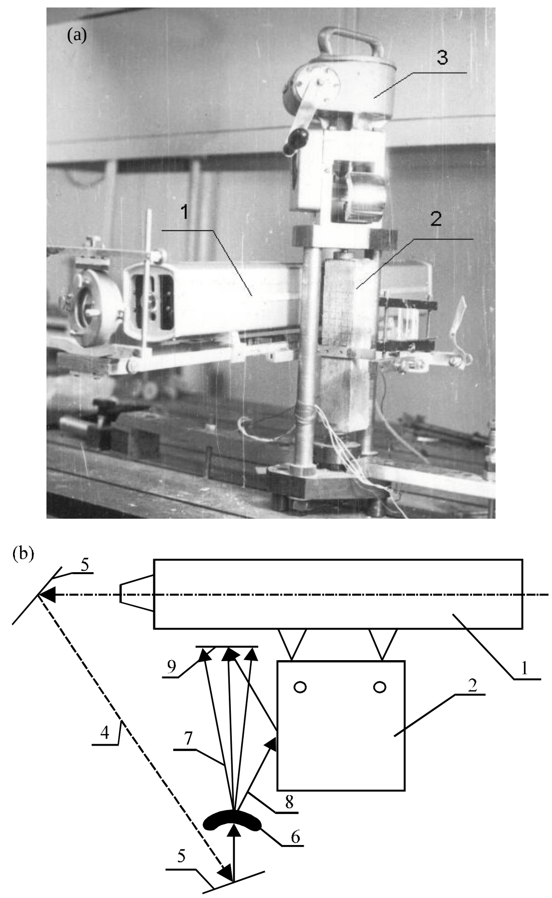


Fig. 1: a) Design of the loading device with the interferometer and b) the schematic diagram of realization of holograms' record; 1: LG-52-2 laser; 2: studied object; 3: loading device; 4: beam radiated by the laser; 5: reflecting mirrors; 6: disseminating lens; 7: basic beam; 8: subject beam; 9: photo plate (hologram)

Table 1: Characteristics of the experienced samples

| Type of samples | Scheme of reinforcement | Basic eccentricity e (mm) | Compaction | No. of samples |
|---|---|---|---|---|
| 1 | 1 Ø3 S 500 | 50 | 1 | 2 |
| 2 | 2 Ø3 S 500 | 50 | 2 | 2 |
| 3 | 2 Ø3 S 500 | 25 | 2* | 2 |

*A compression case without cracks in "stretched" section zone

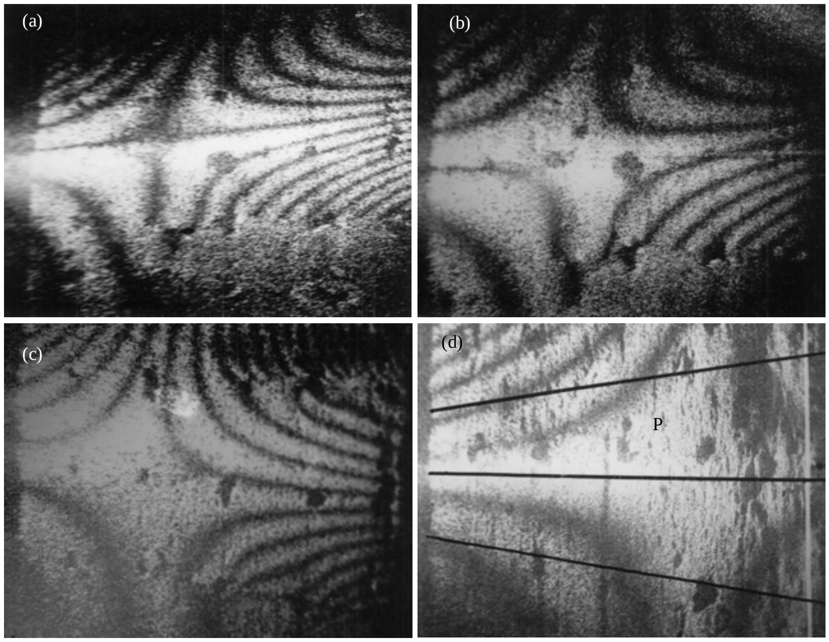


Fig. 2: Characteristic type of interferograms from sets of samples' researches of; a) 1st; b) 2nd and c and d) 3rd types

If to change a supervision point on the hologram, moving parallel to a longitudinal axis of a sample, "the cross" will move on a side surface in the same direction and on too distance as the observer. Analyzing the specified character of strips it is possible to draw a conclusion that at equality of corners of lighting and supervision crossing of strips is always at the level of zero increments of deformations. Thus without resorting to interpretation of interferograms by only qualitative analysis it is possible to establish rather precisely the provision of a neutral axis at any stage of loading of a sample.

It is very simply to define and distribute the deformations on a studied side. Let, the interferogram be received at its supervision from some point lying in the plane P (Fig. 2d), passing through the shining source perpendicular to a longitudinal axis of an element. For points of a surface of the lateral side, lying in the planes P, sensitivity to movements along an axis of a sample it will be equal to zero. During removal from this plane sensitivity to movements along an axis will increase. We will choose two sections on the interferogram, perpendicular to a longitudinal axis of a sample and located on the different parties from the plane P as equals distances from it (Fig. 2d). For these studies on the general there are schedule curve distributions of serial Numbers (N) of interferential strips along section, considering for the zero the strip forming "a cross"'. The sum of abscissae of two curves ($\sum N_x$) will be connected with deformation ($\varepsilon_x$) by a ratio:

$$\varepsilon_x = \frac{2\cdot\lambda\cdot L^{-2}\cdot\sum N_x}{\left(\sqrt{(0.5L)^2+(B+x)^2+c^2}\right)^{-1} + \left(\sqrt{(0.5L)^2+(a\text{-}B\text{-}x)^2+d^2}\right)^{-1}} \quad (1)$$

Where:

- x = The coordinate counted from the next edge along considered sections
- a, B = Distances from the hologram to a shining source and to the next edge, respectively
- c, d = Distances from a supervision point to a shining source and to the object plane
- L = Distance between sections
- λ = Length of a wave of a laser beam ($\lambda = 0.6328/mm^3$ for the LG52-2 laser)

Equation 1 is received in the assumption of symmetry of movements concerning the plane P. This assumption is carried out on condition of a symmetric arrangement concerning the plane of P elements of the interferometer fixing to the object (Semyonov, 1985; Alexandrovsky, 1982).

The size of deformation registered on each hologram was considered at data processing as an increment of deformations of the previous stage of loading. The provision of neutrally axis, thus was defined by the way of direct measurement of the valid image of the interferograms. The measurement was restored full-scale without distortions. General view of the final of distribution diagram of deformations (Fig. 3) including the stage of work of

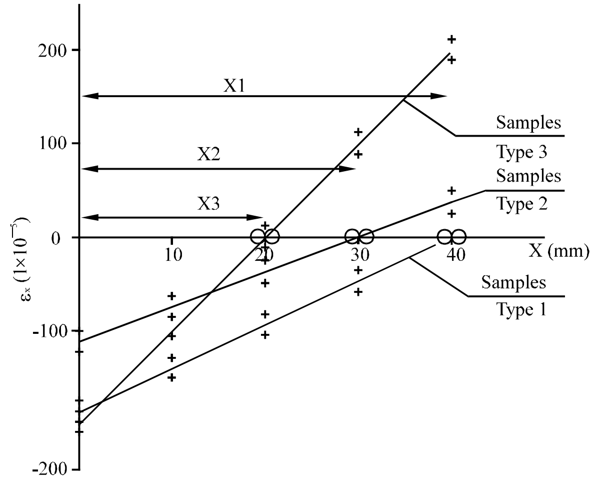


Fig. 3: Distribution diagrams of distribution of deformations on section height in the planes P of the studied objects constructed on the basis of interpretation of interferograms

the elements, close to destruction are constructed on the basis of interpretation of interferograms using Eq. 1.

Quantitative values of the deformations received in this experience aren't of interest and can't be the basis for any generalizations without the corresponding justifications of the principles of modeling. However, the quantitative assessment of distribution of deformations on section height in the form of linear approximation of skilled sizes at an insignificant relative error (<5%) can be very useful in further discussions about a hypothesis of flat sections.

Thus, on the basis of the experiment, it is established that in a method of a holographic interferometry by only qualitative analysis of a picture of the interferation strips, it is possible to receive a full picture of deformations distribution of a side of a ferroconcrete element with high degree of reliability.

Distribution of deformations on height of cross sections of the studied samples and the provision of the neutral axis, received after interpretation of holograms showed the dependence close to linear, reflecting proportional communication of average deformations and distances to a neutral axis that confirms justice of a hypothesis of flat sections.

**Characteristics of concrete tension of the squeezed zone of ferroconcrete units reinforced by steel of the class S800:** In studies, normal to the longitudinal axis of ferroconcrete elements at action of longitudinal forces and the bending moments, tension in concrete of the squeezed zone develop in the conditions of non-uniform distribution of deformations. Existence of a gradient of deformations at non-uniform deformation of the squeezed zone has essential impact on design work as a whole that has to be considered in a settlement assessment of their durability (Beglov *et al*., 2004). Influence as also reinforcing of the squeezed zone of concrete by high-strength grades of steel of the class S800 is very considerable as numerous experiments (Belikov, 1969; Popkov, 1988; Popkov *et al*., 2001; Riskind, 1982; Surin, 1981; Griezic *et al*., 1998; Ford, 1981) show above. Collaboration on concrete and fittings compression with high limits of fluidity increases bearing ability of designs in 1.3-1.8 times in some cases in comparison with bearing ability of the designs which are reinforced by soft steels. Specification for the above called conditions of deformation of distribution diagram concrete of tension distributions in the squeezed zone is represented to be necessary for the purpose of further improvement of settlement models of ferroconcrete designs.

For obtaining data, using results of experiments about the characteristics of concrete tension of the squeezed zone there is the analysis of the deformed condition of prototypes in limit stages by means of equilibrium levels which allows to establish the size of the effort perceived by concrete of the squeezed zone and the provision of an axis of its action and also conditional coefficient of distribution diagram completeness of tension distribution. These characteristics of tension give the chance to judge, though indirectly about form parameters of distribution diagram in concrete of the squeezed zone. Size of equally effective tension in concrete of the squeezed zone ($N_c$) was defined from the condition of balance of longitudinal forces:

$$N_c = N_u - \sum \sigma_{si} \cdot A_{si} \quad (2)$$

Where:

$N_u$ = A skilled maximum load enclosed to a sample

$\sigma_{si}$ = Tension in i-reinforcing core, received on the measured deformations in a unit and in the tested samples of steel according to the actual diagram $\sigma_s$-$\varepsilon_s$

$A_{si}$ = Area of cross section of reinforcing cores of a unit

Position of the line of the effort action, perceived by concrete of the squeezed zone ($N_c$) was defined by distance ($z_c$) to an axis of the area passing through the center of gravity of less squeezed square or stretched fittings from a condition of balance of external and internal forces of section on a Eq. 3:

$$z_? = \frac{\left(N_u e - \sum \sigma_{si} \cdot s_{si}\right)}{N_s} \tag{3}$$

Where:

e = Eccentricity of external force concerning the same axis taking into account the measured deflection

$S_{si}$ = The static moment of the section area of i reinforcing core concerning the same axis

The (ω) relation of average tension in concrete of the squeezed zone ($\sigma_{m.c}$) to the prismatic durability of concrete ($f_c$) or coefficient distribution diagram completeness of tension were calculated on a Eq. 4:

$$\omega = \frac{\sigma_{m \cdot c}}{f_c} = \frac{N_c}{B \cdot x \cdot f_c} \tag{4}$$

Where:

B = Section width

x = Height of the squeezed zone of the concrete, received from experiments

Equation 2 and 3 work of the stretched concrete on a crack is not considered as in a destruction stage it has no noticeable impact on $N_c$ and $z_c$. The area center of gravity position of distribution diagram of tension is characterized by coefficient β which represents the distance relation from the line of action of effort $N_c$ to the squeezed side by height of the squeezed zone:

$$\beta = \frac{(d\text{-}z_c)}{x} \tag{5}$$

where, d distance from the axis passing through the center of gravity of the area of less squeezed or stretched fittings to the most squeezed side of section of an element.

Curve ω-ξ (Fig. 4) constructed according to experiences, reflect a tension of concrete of the squeezed zone in the stage preceding destruction and they also have a minimum at the eccentricities, close to kernel ($\xi = x/d \approx 1$). With increase of eccentricities outside a kernel of section, the values increase, coming nearer to the unit. This property of parameter is a characteristic for a case of reinforcing of the squeezed zone by high-strength steel. When using soft reinforcing steels in ferroconcrete elements, the coefficient with increase of eccentricity outside a section kernel doesn't change. Even at small percent of reinforcing high-strength steel of ρ = 1.15% (Popkov, 1988), we can observe increase of values ω with increase of eccentricity of external force or with reduction of height of the squeezed zone. With the same height of the squeezed zone higher percent of reinforcing by high-strength steel causes increase in completeness distribution diagram tension in concrete.

Nature of changes β in a limit stage on durability (Fig. 4) is influenced by percent of reinforcing of a sample.

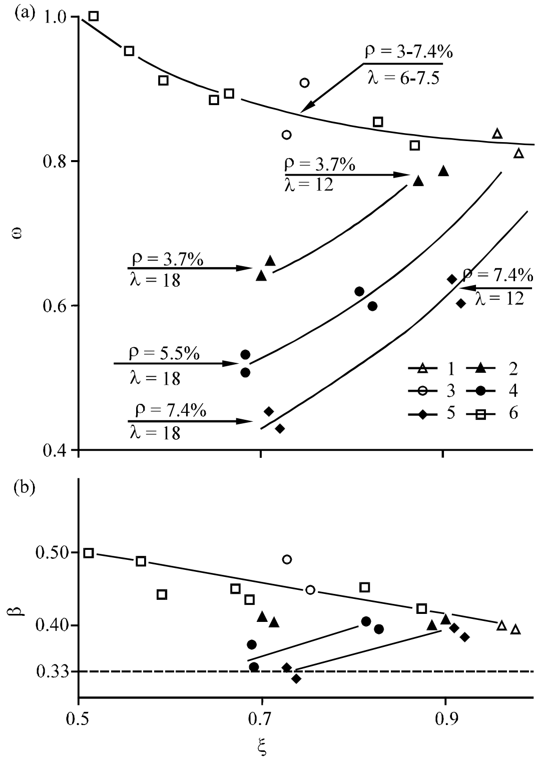


Fig. 4: Dependence of coefficients ω and β from the relative height of the squeezed zone ξ; 1-5: experiment of Semyonov (1985), Popkov (1988) and Popkov *et al.* (2001); 6: experiments of Riskind (1982) and Surin (1981)

The more the percent of reinforcing is the faster the parameter β reaches the highest value = 0.5. The smallest values β correspond to eccentricities, close to the kernel ones.

The numerous results of research given in works (Basovets, 1999; Popkov, 1988), show that the value β decreases to 0.33 and value ω to 0.5 with increase in durability or decrease in inelastic properties of concrete of the squeezed zone. Redistribution of tension in the squeezed zone of the ferroconcrete element, causing curvature of distribution diagram of tension is connected with inelastic deformations of concrete. Therefore, at reduction of the last ones, it is possible to expect a form approach of distribution diagram of tension to the triangular. Increase in inelastic deformations is characterized by movement of a point of the appendix of equally effective efforts in concrete of the squeezed zone towards a neutral axis that leads to increase of values β to 0.5 and ω to 1, equal a rectangular shape of distribution diagram of tensions. In short prototypes (Basovets, 1999; Belikov, 1969; Popkov, 1988; Riskind, 1982) from heavy concrete of rather high durability ($f_c$ = 45.2-48.7) having the lowered ability to redistribution of tension, even at the eccentricitieson border of a kernel of section ($\xi$ = 0.85- 0.9), we got quite high average values of distribution diagram of tensions ($\omega$ = 0.87 are received; $\beta$ = 0.42). According to researches (Belikov, 1969), samples without reinforcing from concrete are approximately of the same durability ($f_c$ = 46.08 MPa), tested for non-central compression with kernel eccentricity had smaller values of characteristics of distribution diagram of tensions of the squeezed zone ($\omega$ = 0.734; $\beta$ = 0.34-0.35) and outside a section kernel they practically didn't change. Skilled results of researches of the bent elements, reinforced by steel of strengthened extract, allowed noticing some increase in completeness of distribution diagram of tensions in concrete of the squeezed zone at reduction of values $\xi$ that will be coordinated with the data, obtained in these researches.

Parameters of concrete work of the squeezed zone $\omega$ and $\beta$ (Fig. 4) for the samples with flexibility $\lambda$ = 12 and for the samples with flexibility $\lambda$ = 18 have smaller values than for the short samples ($\lambda$ = 6). This results from the fact that by the time of loss of designs' stability when the greatest load of the sample is reached, the squeezed zone has margin of safety thanks to which the element continues to bear the falling loading at the accelerated development of deflections, deformations and redistribution of tension in concrete up to its destruction. Thus, destruction of short racks happens at the same time to achievement of the maximum longitudinal force and destruction of average sections of flexible racks is observed after loss of stability and exhaustion of durability of the squeezed zone. This is the main feature and difference of work of the flexible squeezed elements from the short ones.

From the analysis it becomes obvious that at presence of high-strength rod in the squeezed zone, the inelastic properties of concrete considerably increase and they promoting redistribution of tension on less loaded sites of the concrete. With increase in percent of reinforcing or with reduction of height of the squeezed zone this property is shown in a bigger measure.

The coefficient $\beta$ characterizes relative situation in the section of the center of distribution diagram gravity of tension in concrete or of the appendix point of equally effective efforts, perceived by concrete of the squeezed zone of prototypes. The analysis of possible deviations in a settlement assessment of the moment of effort perceived by concrete of the squeezed zone is of interest also at a conditional rectangular shape of distribution diagram of tension in concrete. Such, analysis is carried out, proceeding from conditions of equality of the effort, perceived by concrete of prototypes and the effort perceived by concrete at conditional rectangular distribution diagram of tension, equal to prismatic durability. The ratio is thus considered as:

$$z_\beta = \frac{z_c}{z_d} \quad (6)$$

where, $z_c$ distance from the area center of gravity of the squeezed or stretched fittings to an appendix point of equally effective $N_c$, received on a Eq. 3; $z_d$ distance from the same axis to an appendix point of equally effective in $N_c$ conditional of rectangular distribution diagram of tension, calculated by Eq. 7:

$$z_d = \frac{(h_o - 0.5 \cdot N_c / f_c \cdot b)}{N_c} \quad (7)$$

In the analysis of changes $z_\beta$, depending on relative eccentricity and the percent of reinforcing, it is established that in most cases skilled results exceed the settlement. Average size is very close to the unit ($z_\beta \approx 1.053$). Mean square deviation of an average ($\sigma_x = 27\times10^{-2}$) and variation coefficient ($\upsilon = 6.1\times10^{-2}$) are very small, therefore, points of the appendix of equally effective efforts in the conditional rectangular squeezed zone and the equally effective squeezed zone of prototypes can be considered to be almost coincident in a limit stage on element durability.

The considered parameter of concrete tension of the squeezed zone $\omega$ characterizes the size of average tension at a conditional rectangular shape of distribution diagram, i.e., at uniform distribution of tension on the area. The high rates of coefficient $\omega$ reaching sizes 0.9-1.02 and also, a curvilinear outline of actual distribution diagram of tension allow to assume that the maximum tension in concrete of the squeezed zone exceeds the prismatic durability.

Having set by the form distribution diagram (Fig. 5) of tension distribution in concrete to the squeezed zone close to actual, it is possible to estimate (though approximately) the values of the maximum tension. The initial criterion of a choice of an distribution diagram form can be coefficient $\beta$, reflecting provision of equally effective efforts in concrete of the squeezed zone. The taken form of distribution diagram has to correspond to the changes of a center of gravity position of its area, observed in the experiments. In the range of changes from $\beta$ 0.33-0.5, for example, a trapezoid distribution diagram can be of this requirement. Conditional coefficient of completeness of this distribution diagram ($\omega_d$) and the maximum tension ($\sigma_{cu}$) are determined by Eq. 8 and 9:

$$\omega_d = 0.5 + 0.25 \cdot (3 \cdot \beta - 1) + 0.5 \cdot \left[0.25 \cdot (3\beta - 1)^2 - (1 - 3\beta)\right]^{0.5} \quad (8)$$

$$\sigma_{cu} = f_c \cdot \frac{\omega}{\omega_d} \quad (9)$$

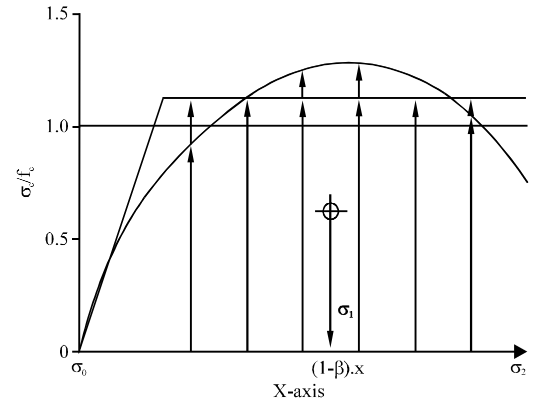


Fig. 5: Distribution diagram of tension in concrete of the squeezed zone in the form of conditional rectangular, linear and curvilinear trapezes

Proceeding from the standard ideas of nature of distribution of tension in concrete of the squeezed zone of section in a destruction stage, actual distribution diagram has a curvilinear outline with the greatest ordinate in depth and a descending branch at an element side (Smolyago *et al*., 2010). If to take the form of distribution diagram in the form of the curvilinear trapezoid (Fig. 5) which has the size of tension on the end of a descending site or at the section side, = 0.8 $f_c$, the ordinate of the maximum tension can be found on effort in concrete of the squeezed zone ($N_c$) received from the experiment or the area of the distribution diagram ($A_\sigma$) by Eq. 10:

$$A_\sigma = \int_0^x f(x)dx \tag{10}$$

The value of the integral with a sufficient accuracy for practical calculations can be determined by Simpson's approximate formula for curvilinear trapezoids:

$$\int_0^x f(x)dx \approx \frac{X}{6} \cdot (\sigma_0 + 4 \cdot \sigma_1 + \sigma_2) \tag{11}$$

having accepted $\sigma_0 = 0$; $\sigma_1 = \sigma_{Bu}$; $\sigma_2 = 0.8\ f_c$; we will transform expression Eq. 11 to the view:

$$\sigma_{cu} = 1.5 \cdot \frac{A_\sigma}{X} - 0.2 \cdot f_c \text{ or } \sigma_{cu} = 1.5 \cdot \frac{N_c}{A_\sigma} - 0.2 \cdot f_c \tag{12}$$

The values of the maximum tension calculated by Eq. 9 and 13 in concrete of the squeezed zone in most cases for short samples surpass the prismatic durability of concrete (Fig. 6), reaching sizes 1.2-1.4.

The essence of these phenomena consists in the property inherent mainly in concrete. From some level, loads on the sample of tension in concrete at the most

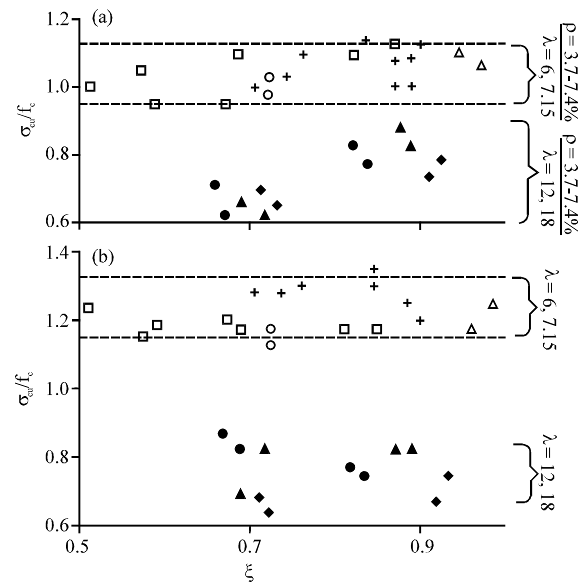


Fig. 6: a) The maximum tension in concrete of the squeezed zone at conditional the distribution diagram in the form of linear and b) curvilinear trapezes (symbol in Fig. 4) values of maximum tension in concrete of the squeezed zone of flexible elements in a stage of loss of stability are lower than prismatic durability and they make 0.6-0.8

squeezed side of section reach their strength. At further loading, concrete in this part of section isn't capable to perceive increasing loading. However, it doesn't lead to element destruction. Due to joint deformation under the influence of squeezing efforts fittings and concrete have mutual impact on distribution of efforts and tension among themselves. Thanks to what fittings as more rigid and elastic material, perceives that part of efforts which concrete isn't capable to bear after achievement in it limit tension. Thus, work of concrete passes to a descending branch of the chart of compression of "tension deformation" which is characterized by increase of longitudinal deformations that in turn, allows reaching tension in the squeezed high-strength fittings about 1000 MPa and more. That is thanks to the possibility of redistribution of efforts from concrete on fittings; section is capable to bear increasing loading. Besides, at a non-uniform tension, tension is redistributed not only between concrete and fittings but also in concrete on height of the squeezed zone on its less intense sites. In the depth of section concrete is deformed in the constrained conditions that lead to increase in tension and movement of ordinate of the maximum tension from more loaded or even collapsing area near the squeezed side in the central, less intense part of the squeezed zone. As for the valid work of ferroconcrete designs near the squeezed side of section, it is expedient to take into account the existence of a descending branch of the diagram "tension deformation" for concrete which is characterized by increase of longitudinal deformations and decrease in tension.

As a result of a number of numerical experiments we studied various options of transformation of the diagram $\sigma_c$-$\varepsilon_c$ for axial compression, taking into account the intensed and deformed condition of prototypes by introduction of correction coefficients $\gamma_f$ to $\gamma_c$ the values $f_c$ and $\varepsilon_c$, respectively to coordinates of the main basic point of the diagram of the concrete condition. It is thus noted that without introduction the corrected coefficients to the description of the diagram of concrete deformation of the squeezed zone, the settlement bearing ability underestimates to 40% which was seen from the experiments. With the help of correction of the coefficients we received the maximum rapprochement of calculated and skilled values of limit efforts and deformations in the size of coordinate of a basic point on an axis ε of the diagram calculated by Eq. 13:

$$\varepsilon_{xc} = \lambda_\varepsilon \cdot \varepsilon_c = \frac{2.19\text{-}0.2 \cdot \rho\text{-}\lambda}{60} \quad (13)$$

Where:

- λ = The flexibility of a design accepted in calculation of $\lambda \leq 15$
- ρ = Percent of reinforcing of section by longitudinal high-strength fitting (at $\rho > 4.7\%$ accepted as $\rho = 4.7\%$)

## DISCUSSION

- Use of a holographic method in the experimental study by only qualitative analysis of a picture of interferential strips allowed receiving a full picture of distribution of deformations of a ferroconcrete element surface with high degree of reliability
- Distribution of deformations on height of cross sections of the studied samples and the provision of the neutral axis, established after hologram interpretation, showed the dependence close to linear, reflecting proportional communication of average deformations and distances to a neutral axis that confirms justice of the hypothesis of flat sections
- We have revealed a feature of work of the flexible racks, consisting in a stage of stability loss at achievement of the maximum, loading durability of the squeezed zone is not settled, thanks to that the sections continue to bear falling loading at the accelerated development of the deflections, deformations and redistribution of efforts in concrete up to its destruction. Destruction of short racks happens from achievement of limit tension in a material, i.e., on durability and destruction of sections of flexible racks is observed after loss of stability after which there comes destruction of the squeezed zone of section at the fallen loading
- On the basis of the analysis of concrete tension characteristics of the squeezed zone of the ferroconcrete designs which are reinforced by steel of S800 class and more, it is offered to use in the general deformation method of calculation the transformed diagram "tension of deformation" for the concrete. The diagram considers influence of non-uniform distribution of deformations, high-strength steel and flexibility of the squeezed elements

## CONCLUSION

On the basis of the experimental studies of the deformations' field of concrete of the squeezed zone of non-centrally loaded ferroconcrete elements by holographic method and also with the help of the test results of prototypes of such designs of other researchers, it is possible to make the conclusions.

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