ZI methodology and ZI method: an o v e r v i e w

Ipolitas Židonis

Klaipėda university, Bijūnų g.17, LT-91225, Klaipėda, Lithuania, email: ipolitas.zidonis@gmail.com

1. Preface

The present paper is of purely informational nature. It is not intended to solve any new problems, it is rather intended to assist the readers to grasp the gist of the ZI methodology and the ZI method(s) with minimum effort investment and to evaluate the ZI methodology in comparison with other methodologies currently used for analogous purposes. The author is convinced that such a comparison would eventually reveal that the ZI methodology has numerous advantages over alternative methodologies.

The ZI methodology is a result of many years of the author's scientific research pursuits. The multiple pieces of information of the ZI methodology are scattered across multiple publications. Readers would have a hard time to assemble the and evaluate them. Such a pursuit would cost readers a lot of time and effort. Therefore, in the present paper, the author the ZI method presents a *concise summary* of the pieces of the information amassed from various sources as well as its overview and evaluation. With minimum investment of time and effort, the readers will be able to build opinions of their own of the gist of the ZI methodology, the ZI methods and the ZI method. The readers will also be able to evaluate the innovations and their potential.

For the sake of brevity, here and hereinafter in the present paper we will use a single umbrella term to denote the three terms (ZI methodology, ZI methods and ZI method). Instead of *ZI methodology, ZI methods and ZI method*, we will hereinafter write *ZI methodology*. The ZI methods and the ZI method are elements of the ZI methodology.

The most important information on the ZI methodology in publications published before 2017 was collected and used in monographs [1 and 2]. The English text of monograph [1] is identical to the Lithuanian text of monograph [2], i.e. the Lithuanian text of the monograph [2] was translated into English. Monographs [1 and 2] have the same numeration of their chapters and equations. Their page numeration of the two monographs [1 and 2] may differ, though. The present paper's references to both monographs are equally valid for each of them. Therefore, when the present article refers to both monographs simultaneously, any of the versions of the monograph may be referred to. The readers are free to choose the one which is more handy to them.

The present article contains more information than the monographs, e.g. it also supplies the information of article [3]. In addition to that, the information contained in the monographs is used in a different manner. In this article, all information currently available was reviewed, evaluated and presented in a *concise* manner.

The more important the issue, the more information on it is supplied in the present paper. A theoretical calculation of the position of the neutral axis of the structural members (items 15 and 16) was given more attention than other issues.

On extremely topical issues the article also provides the most recent factual data. Item 8 repeats part of very important most recent information of article [3] on the reliability of stress-strain diagrams for concrete in compression. The most important scientific innovations of article [3] are: (1) the method of increasing the reliability of the stress-strain interdependence of concrete in compression of the EN-2 Regulation in the ZI methodology as described in item (8); and (2) the improved method of calculating the strength of heavily reinforced reinforced concrete members.

The present informational article also contains excerpts from other publications of the author, in cases where any such excerpts help serve the purpose of the article.

2. Introduction

The ZI methodology, ZI methods and ZI method. What are they?

The ZI method is a system of certain calculation rules. The rules hold good within a given scope, in a given environment, within given field limits. A method is a tool for implementing the rules of methodology. It is a tool for solving specific tasks.A methodology may have more than one method. For example, in the ZI method, the stress-strain interdependence description method, the method for calculating the neutral axis position of structural members, the method for calculating the strength of amply reinforced beams (article [3]), the column strength calculation method, the eurocode stress-strain curvilinear diagram reliability increase methods (article [3]), etc. But the whole group of smaller methods can be also called a single method. It encompasses the goals of all the minor methods. This was the case in monographs [1 and 2].The minor methods are all elements of the general comprehensive method. In the general case, the concept of a methodology is broader than that of a method. A method is an element of a methodology. It may comprise part of the space of a methodology space or its entire space. In the latter case, the gist of the concept of a method coincides with that of the concept of a methodology. The characteristic of the method is also the characteristic of the methodology. The monographs [1 and 2] use the concept of a single method.

The present article uses information on the ZI methodology and the ZI method from various publications. Most of the information can be found in monographs [1 and 2].

As of the moment of the publication of the present article, there is also certain new information that was posted. Thus the environment of the methodology is effectively vaster than that of the monographs.

Article [3] introduces some new additional information. Article [3] and the present informational article may be regarded as annexes of the monographs [1 and 2]. In the future, there will probably emerge still further methods of the methodology. At present an alternative method for calculating beam curves is under development.

The ZI methodology is presented as an alternative to other methodologies that are currently most frequently used for similar purposes. The positive and negative qualities of different methodologies are compared.

3. The purpose of the present paper

The purpose of the present paper is to overview *the ZI methodology and methods*, to compare various alternative methodologies, to evaluate the advantages and disadvantages of the methodologies, to summarize the results and to present them to the readers in a *concise* manner.

The pieces of information on ZI methodology and methods were collected from various publications of the author.

The article demonstrates certain new possibilities offered by the ZI methodology. The ZI methodology and methods are superior to other methodologies currently used for analogous purposes.

The ZI methodology, just like other methodologies, was designed for a certain specific computational domain of certain structures. To explain the gist of the ZI methodology, the article uses an example of reinforced concrete structures. Reinforced concrete structures are widely used in practice. Reinforced structures are quite complex; they may be either without cracks or they may have cracks. We sometimes have to deal with cross sections in beams without cracks, in beams with cracks, in their cross-sections at cracks or between cracks.

The present article is meant for those interested in methodologies and methods of calculating structural members such as beams, columns and the like that are subjected to bending and compression, the possibilities offered by them, their advantages and disadvantages.

The information presented in a *concise* manner in the present article can speed up the use of the alternative ZI methodology and methods, which is of both practical and theoretical importance.

4. A n n o t a t i o n of the ZI methodology and ZI method

The potential of the ZI methodology and the ZI method exceeds that of other methodologies currently used for analogous purposes. The calculation methods are both more advanced and more varied. The calculations are more realistic and more accurate. Within the domain of the ZI methodology, we are able to solve problems that defied solution before. The method is used to calculate the stress-strain state parameters of various structural members subject to bending moments and axial forces (i.e. beam structures of buildings, viaducts, bridges, columns, etc.) in sections perpendicular to the axis of the structural members. The equations are suitable for calculating parameters of structural members in sections without cracks, in tensile zone sections at cracks or between cracks. The methodology is suitable for the analysis of stress-strain state at cross-sections at the initial partially closing cracks. The methodology is suitable for structural members that are layered, that are variously reinforced, that are made of different materials and that have different cross-sectional shapes. It is possible to use not only the curvilinear diagrams that were created by the author, but also triangular, rectangular and other kinds of stress diagrams or their combinations. The methodology also allows for the possibility of ignoring the stresses.It is a single universal method and equations for solving various tasks in both elastic and elastic plastic stages, both where the structural members have cracks and where they have no cracks. The same equations hold good for any loading intensity all the way up to the breaking stage of the structural member.And the values for each individual parameter that are calculated are not merely conditional or cumulative values, but they rather are the actual values of each individual parameter. The real values of forces (bending moments, forces), strains, stresses, compressive, tensile zones and crack height and other parameters may be calculated at any loading stage. The general equations of the method are quite universal and therefore quite complex. But when it comes to solving a particular problem, then any unnecessary members of the equations are eliminated, and as a result simpler or even very simple equations are obtained. In some cases, in this way, from the universal equations developed by the author it is possible to obtain the simple equations of materials resistance that are currently used. The methodology is both of theoretical importance and of practical importance. It is aimed not only at civil and industrial engineering researchers, doctoral students, engineers designers, manufacturing engineers, but also at lecturers, graduate students and undergraduates both of the bachelor and master programmes.

5. Conditions for possible use of the ZI methodology

The scope of the ZI methodology includes:

1) Structural members under bending and compression *subject to bending moments and / or axial forces* (e.g. beams and columns of buildings, beams and columns of bridges and overpasses, truss rods, etc.), when
2) *Bending moments and / or axial forces* act on the symmetry plane of the structural members.
3) Calculations are made at normal sections (cross-sections) of structural members.

We do not address the operation of tangential stresses, oblique bending, and a number of other issues beyond the scope of the ZI methodology.

6. Criteria (domains) for comparing the possibilities offered by the ZI methodology with alternative methodologies

Factors of methodologies that are subject to comparison:

Stress-strain state parameters (compressive and tensile zone and crack height values, stress and strain values) that are calculated at cross sections (cross sections perpendicular to the axis of the structural members).

Realism of intermediate values of the parameters on which the end result depends (e.g. curve, inclination).

Estimation of threshold states of structural members by the limit states method.

Practical utility.

Scientific utility.

Evaluation in terms of enduring scientific value.

Evaluation from the point of view of didactics: simplicity, clarity, consistency, comprehensibility, practicality, realism, universality, and integrity.

Computational complexity.

According to these criteria, the ZI methodology has advantages over other, alternative, methodologies. Exception: computational complexity: The ZI methodology requires solving a multi-step equation. But these days it is not a problem.

For example, let us consider the case of reinforced structures such as, for instance, reinforced concrete. At present, for any such calculations the method that is mainly resorted to is the safety limit states method. The method consists of a set of ultimate limit states (ULS) equations and a set of safety limit states (SLS) equations. The use of the safety limit states equation sets enables meeting the main practical end goals (calculating the strength of structures, curves, deflections, wedges). But in the absence of intermediate values, the values of parameters are usually inaccurate and unrealistic.

In this respect, the ZI methodology, in its intended contexts, has advantages over alternative methodologies.

7. The gist of the ZI methodology

The gist of the ZI methodology is as follows:

1. Possibility to easily calculate axial forces, bending moments, eccentricities of forces in cross-sectional areas of structural members (rectangular areas, reinforcements, attenuations) (item.1.6 of monographs [1 and 2]).
2. Possibility to assume as input parameters ω_n and ω_m for the calculations not only in non-linear diagrams, but also in diagrams of other shapes (triangular, rectangular, trapezoidal, fixed part of non-linear diagrams, etc.) The stresses may be disregarded altogether.
3. There are three equations of equilibrium of forces. Two of the equations, the first one and second one, the one of axial forces and the one of the bending moments are independent, and the third equation is derived from the first two equations.
4. For the calculations, it is only necessary to have stress-strain interdependencies of the layers of the structural member.
5. Possibility to make a theoretical calculation the actual position of the neutral axis of the cross section of structural members. The ZI method enabled resolution of a very pressing and difficult problem (section 2.2.2 of monographs [1 and 2]).

8. Eurocode's EN-2 curvillinear stress-strain interdependence for concrete in compression in the ZI methodology and a method for the increase of the reliability of the interdependence

The reliability level of the strain diagram that is presented in the eurocode EN-2 and in STR (Fig.1) is 50%. Such reliability level may be used for the analysis of test results. The computation of serviceability limit states (SLS) requires the level of reliability of 95%, and the computation of ultimate limit states (ULS) requires the level of reliability of ~100%.

The eurocode EN-2 and the Lithuanian regulation contain the following equations ensuring the reliability of 50% (article [3]):

$$E_{cm} = 22(f_{cm}/10)^{0.3} \text{ (GPa); } (f_{cm}\text{, MPa}) \quad (1)$$

$$\varepsilon_{c1} = 0.7 f_{cm}^{0.31} \le 2.8 \text{ (‰); } (f_{cm}\text{, MPa}) \quad (2)$$

$E_{cm} = \tan\alpha$ – cut strain module (Fig. 1.).
$E_c = 1.05 E_{cm}$ – elasticity module.

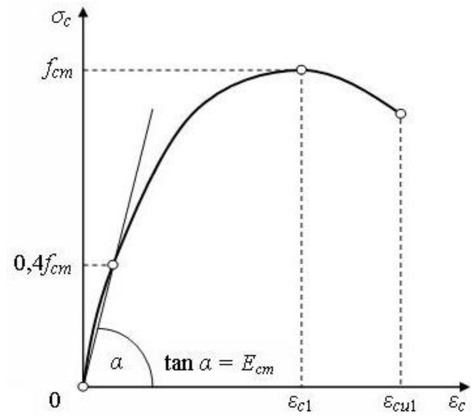

Fig. 1 Eurocode's EN-2 concrete stress-strain interdependence

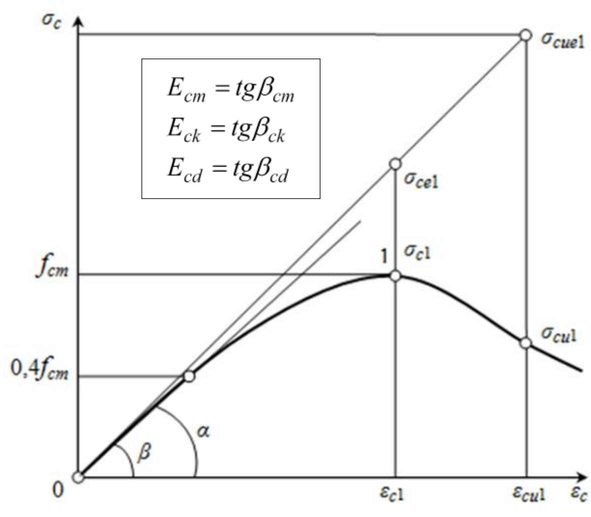

Fig. 2 In the ZI methodology a 3rd degree stress-strain interdependence for concrete is assumed

In the ZI methodology:

$$\sigma_c = \nu_c E_c \varepsilon_c \tag{3}$$

$$\nu_c = 1 + c_1\eta + c_2\eta^2 = 1 + (3\nu_{c1} - 2)\eta + (1 - 2\nu_{c1})\eta^2 \tag{4}$$

$$\nu_{c1} = \frac{\sigma_{c1}}{\sigma_{ce1}} = \frac{f_c}{E_c \varepsilon_{c1}} \tag{5}$$

$$\eta = \varepsilon_c / \varepsilon_{c1} \tag{6}$$

In the ZI methodology, for the curvillinear concrete stress-strain function (Fig. 2) the input data assumed are as follows:

1. When the reliability is 50 %, then E_{cm} from equation (1), ε_{c1} from equation (2), the elasticity module $E_c = 1.05E_{cm} = tg\beta_{cm}$, $\sigma_{c1} = f_{cm}$.
2. When the reliability is 95 %, then E_{ck} from equation (1), ε_{ck1} from equation (2), instead of f_{cm} if we assume f_{ck}; the elasticity module $E_{ck} = tg\beta_{ck}$, $\sigma_{c1} = f_{ck}$.
3. When the reliability is ~100 %, then E_{cd} from equation (1), ε_{cd1} from equation (2), instead of f_{cm} if we assume f_{cd}; the elasticity module $E_{cd} = tg\beta_{cd}$, $\sigma_{c1} = f_{cd}$.

A reality check of case 3 was made in article [3]. The results that were obtained were good.

9. A very brief description of the ZI methodology

The methodology that is presented is a quite simple (understandable even to middle-level technology students), clear, universal, practical, uniform, realistic (takes into account the actual properties of materials) methodology for calculating stress-strain state parameters in perpendicular cross-sections of structural members.

The methodology is applicable to any loading stage (load intensity) to cross-sectional areas in the pre-cracking phase, to cross-sectional areas at the crack and between the cracks.

The entire scope of the ZI methodology is covered by a uniform system of possibilities and requirements that hold good for all the ZI methods.

The potential of the ZI methodology is bigger than that of other methodologies currently used for analogous purposes.

The calculation methods are both more advanced and more varied. The calculations are more realistic and more accurate. Within the domain of the ZI methodology we can solve problems that we could not solve before.

10. The most important properties of the ZI methodology:

1. Simplicity.
2. Realism of the calculation results.
3. Suitability for the full range of loading stages, even where other alternative methods are not suitable.
4. The ZI methodology can substitute the entire equations groups system currently used in analogous calculations. For the entire range of loading options, the ZI methodology employs the same two equations and equations derived from them (calculation methods).
5. The ZI method enables calculations that cannot be made by other methods.

11. The relevance of the ZI methodology

A short historical background:

1. The engineering design standard regulations of building structures of the former USSR and other former Socialist Bloc countries were based on experiments. Such an approach has certain advantages (realism of the calculation results), on the other hand, however, it also has certain disadvantages (the process of the development of the equations is costly and the equations can be used to calculate the parameters of the structural members from the experimental test data of which the equations were originally developed). As still another advantage it may be also mentioned that, in the continuous state of load application, when calculating deflections or crack opening, each of the stress-strain state parameters of the perpendicular section has to be calculated separately, one by one. Multiple parameter values are not summarised. It helps to understand the structural member's state change with ever increasing loads, which is very important when teaching students. Another disadvantage of the methodology is that the methodology is not suitable for estimating values of parameters of structural members at stages close to the formation of cracks and structural member breaking stage.
2. By contrast, the Western Bloc countries decided to follow a different approach. In the West, the equations are mainly developed theoretically, through the employment of the already existing theoretical basis. Calculations are performed in a simpler manner, but also in a more primitive manner, since often the flat-section hypothesis is used even in such cases where it does not suit very well. Therefore, the result of the calculation that is obtained is often more distant from reality.
3. **The ZI methodology** partially offsets the above disadvantages. It is of theoretical nature, but it has the advantages mentioned in item 1. Moreover, the ZI methodology is uniform, i.e. the same methodology and equations are suitable for the calculations at any degree of loading. In respect of all the ZI methods, the same system holds good, i.e. the same ZI methodology possibilities and requirements systems. Meanwhile, in the methodologies as per items 1 and 2, for the individual loading steps (non-cracked members, the breaking moment, permanent cracked elements, strength calculation) different equations are used all the time.

12. The *shortcomings of the methods* **currently most widely used for the calculation of the ultimate limit states**

At present, most methods of calculating the ultimate limit states currently used in practice have quite a few shortcomings.

Where there is no uniform (integral) calculation methodology and where radically simplified (distorted) calculation schemes are used:

- it is necessary to use *a lot of correction coefficients*;
- the empirical equations of these coefficients are sometimes very *bulky and complex* and *their development is very costly*;
- In order to calculate the curvature located in the section near the crack, is required to have data on the strain of the reinforcement in tension and the outermost layer of the compression zone of the concrete. But this time *it is stresses, and not strains, that are being calculated.* The strains are calculated by dividing the stresses by the strain modulus. But its meaning is unknown. The module has to be selected in such a way so that the calculation results are as close as possible to the test results;
- *it is impossible to calculate* or at least to estimate the cracks and tension zone above the cracks height;
- *the calculation* of the position neutral axis (the thickness of concrete compression zone) *is but very conditional*;
- *it is impossible to calculate* stress-strain state parameters in perpendicular sections *at stages before the crack formation and before the breaking of the structural member;*
- *it is impossible to estimate* stress-strain state in the plasticity hinges of multi-axial uncut elements, i.e. in cases where the holding capacity decreases due to the fact that the reinforcement stresses exceed the yield strength and / or the compressive zone concrete stresses exceed the concrete strength limit and begin to decrease;
- it is impossible to calculate the element strength reserve when the reinforcement stresses exceed the yield stresses;
- *there is no method* for estimating the values of parameters of strain-stress state of structural members based on the measured crack parameters (crack width, height, and spaces between the cracks) at stages where loads exceed operational loads;
- *it is impossible to research* the influence of the scaling and stress gradient on the stress diagram and the values of the parameters subject calculation.

13. The gist of the ZI methodology:

1. It deals with the equilibrium of forces of structural members *subject to bending moments and / or axial forces* (bending and compression) at structural member's cross section (at cross section perpendicular to the axis of the member). All the forces act on *the member's cross-section symmetry plane*.

2. The *basic points* on which the ZI methodology is predicated:

   2.1. Within the entire scope of the ZI methodology, there holds good a uniform (integral) system of possibilities and requirements.

   2.2. *Employment of curvillinear stress diagrams* and otherwise shaped diagrams. Since the methodology employs the real stress-strain relationships, thus, *the values* of the calculated parameters (crack height, height of the compression and tension zone, strain and stress) *values are also realistic.*

   2.3. *User-friendly calculation* of the resultant *force F* of the stresses acting on the rectangular area and its *moment M* around the edge of the area and the position of the force in the rectangular area. The position of the force F is calculated in a very simple way*: the e eccentricity is equal to M/N.*

   2.4. *Possibility* instead of real curvilinear stress diagram in equations to also *use various other diagrams*: the "stiff" part of the curvilinear diagram, the rectangle, triangle, etc. diagram. The stresses may be disregarded altogether.

   2.5. *Possibility to factor in into the calculations deviations from the flat-section (Bernoulli) hypothesis.*

   2.6. *Conditions of static equilibrium of forces.*

3. The method is rather simple, clear, universal, seamless, and handy to use.

   3.1. In order to use the method successfully, *it is sufficient to have basic knowledge* of engineering courses generally taught to bachelor students: *course in resilience of elastic materials, building construction mechanics and in building structures*.

   3.2. The same *uniform (integral) methodology* is applicable in case of any moment of acting load (loading stage) right from the very start of the load application to the breaking down of the structural member and even in case of the stage of decreasing of the holding power (e.g. at cross-sections of multiaxial non-cut beam supports). It is possible to calculate not only the strength of the member corresponding to the yield strength of the reinforcement, but also the *maximum strength of the members*, out what is the additional strength reserve which is currently not quantifiable.

   3.3. *It is possible to make calculations at load acting stages close to the crack propagation stages or breaking stages.* At present there is no other handy theoretical (non-experimental) method that would be suited for this purpose.

   3.4. *The method is suitable* for the calculation of values of parameters at cross-sections of structural members *without cracks*, for the calculation of structural members *with cracks*, at cross-*sections at the crack* or *between the cracks*.

   3.5. Structural members *may be of (various kinds of) concrete, metal, wood, plastic, they may be complex, they may be layered.*

   3.6. In general case, structural *member's cross-section may be of any shape, it may have reinforcements or weakenings, it may be not reinforced, or it may be reinforced with steel or non-steel reinforcements* (e.g. glass or carbon fiber, etc.) *at* *any height of the structural member* (not necessarily concentrated at the member height edges).The reinforcement may be *not pre-tensioned or it may be tensioned, or it may be of mixed type*. Its layers may be of various shapes and materials.

4. The cases of 3rd and 5th degree stress diagrams are analysed. *The first case is a simpler one, and the second one is more universal*.

4.1. *The first case*, the case where the 3rd degree stress diagrams are employed, is simpler. More attention is paid to the 3rd degree stress diagram, because in this way many of the most important practical problems may be solved in a simpler way. In most cases the accuracy of the calculation in this way is sufficient and it is not lower (or it is but slightly lower) than that of the more sophisticated 5th degree diagram.

4.2. *The second case*, where the 5th degree diagrams are used, is somewhat more universal, more accurate, but it is also more complex. It is worthwhile using it in case when of interest is the entire "downward slope" part of the stress diagram.

5. Subject to analysis are two cases of beams layers cross-sectional division into computational plots:

5.1. *In the first case,* plots that are of any size and that are made of any material are selected. For the selected place of the plot (which is often the geometric centre) the strains and stresses are calculated. *The resultant force of stresses is assumed as being equal to the stresses multiplied by the area of the plot,* i.e. it is assumed that the value of the stress is uniform throughout the entire area of the plot.

5.2. *In the second case*, it is assumed that the plots (layers) of the main part of the structural member are rectangular in shape. At the height of these plots' stresses vary according to the law of the chosen (3rd grade or 5th grade) function.

5.3. In most cases the handiest mode is the *mixed* mode.

6. Subject to analysis are *two calculation variants.*

6.1. the somewhat more general and universal *iterative* method of calculation (the one of sequential approximation)

6.2. direct calculation method (no approximation)

6.3. In some cases, it is convenient to resort to the mixed method (combination of iterative and direct methods).

7. There are research findings that confirm the realness of the results of the methodology, and data that can be put into practice now, such as for instance:

7.1. The calculation of the strength of reinforced concrete structural members subject to flexion through the employment of a more realistic curvilinear concrete stress diagram (as of today, it is a rectangular diagram is mainly used). Calculation of the strength of abundantly reinforced members is made in a more logical manner. It is no longer necessary to use empirical equations designed to calculate the maximum height (neutral axis position) of the concrete zone. in compression.

7.2. A theoretical solution is provided to one of the most important and difficult problems, namely the one of the calculations of thickness of concrete zone in compression (neutral axis position). At present, the calculation that is made is either but very approximate (resorting to the flat sections hypothesis) or through the employment of an empirical equation, Empirical obtaining and refining of the latter is both complicated and costly. And it is meant only for the calculation in the phase of the use of constructions (in the so-called long-term situation).

7.3. Theoretical calculation is made of such a reinforcement of concrete members prestress value, at the member's estimated decomposition stage, there would simultaneously start the yield of the reinforcement (or some other selected stress value would be achieved) and the stress of the concrete zone in compression would be equal to the selected value (for example, the strength limit).

7.4. In current practice, in order to calculate structural members stress-strain state parameters at cross-sections perpendicular to the axis of the members a rectangular cross-section with or without shelves (or shelf brackets) is assumed. For these cases, monographs supply a methodology and equations that were prepared.

7.5. Most attention is paid to reinforced concrete structural members as their calculation is the most complex one: the members may either be with cracks or without cracks in the tension zone. But the methodology and the equations also apply to structural members made from other materials.

7.6. The ZI method is already employed by students of Siauliai University and Vilnius Gediminas Technical University. For example, Siauliai University undergraduates have made conference presentations and published scientific research articles with the employment of the ZI method Vilnius Gediminas Technical University master programme students used the ZI method in their master theses.

8. The ZI method is kind of development of the currently used method for calculating stress-strain state parameters of elastic materials; the method is suitable for the cases of both elastic-plastic and elastic materials. When we apply the general equations of the method to the case of elastic materials, in separate cases, we obtain the traditional materials resistance equations currently used. The method is of fundamental and applied nature and has a lasting value.

9. *Examples of possible uses* of the ZI method:

9.1. Calculation of parameters of structural members *subject to bending and compression*, e.g. of buildings (beams, columns), beams and supports of bridges and overpasses, truss rods, etc.

9.2. *Analysis* of structural members.

9.3. *Development and testing of simpler (approximate) calculation methods.*

9.4. Improvement of structural members *engineering design regulations.*

9.5. *Preparation of teaching aids* for students of Civil and Industrial Engineering.

9.6. *Preparation of Civil and Industrial Engineering students for scientific research activities.*

10. *It is only necessary to have a stress-strain diagram for the materials* as described in poli-degree polynomial form (by the ZI method). If the diagram is made with taking into account of the long-term operation of the loads or the scaling factor or the gradient of the stress diagram, etc., then the results obtained correspond to these conditions. Thus, it also possible to estimate the long-term load operation (creep) factor.

11.Since the methodology employs realistic (strain relationships, the values of the *calculated parameters* (crack height, height of the compression actual) stress- and tension zone, strain and stress) values are also *real*.

14. Strain models

Terms and Definitions

Linear (elastic) strain model. Its essence consists in the application of stress-strain diagrams of elastic materials.

Curvilinear strain model. It employs curvilinear stress-strain diagrams.

Mixed strain model. Various forms of stress-strain interdependencies are used.

In the Materials Resistance course taught to students of technology the linear model prevails.

In the European and Lithuanian regulations for engineering construction calculations (the standard regulations) the mixed model prevails, often with simplified initial stress diagrams that are very far from reality.

In the ZI methodology, all the above-mentioned strain models may be used. For example, let us consider such reinforced structures as, for instance, reinforced concrete. At present, for any such calculations the method that is mainly resorted to is the safety limit states method. The method consists of a set of ultimate limit states (ULS) equations and a set of safety limit states (SLS) equations. The use of the limit states equation sets enables meeting the main practical end goals (calculating the strength of structures, curves, deflections, wedges). But in the absence of intermediate values, the values of parameters as a rule are inaccurate and unrealistic. Quite a few problems cannot be resolved at all.

The possibility to use in the ZI methodology curvilinear stress-strain functions enables the substitution of all currently used main construction ultimate limit states (ULS) equations calculation methodology equation groups by two equations. In other words, the entire calculation system is changed.

If the stress diagram that is assumed in the ZI method corresponds to the stress diagram valid at the time of the construction calculation, the calculation results will be absolutely accurate. But it is necessary to have such a diagram.

If for the calculations of constructions, stress-strain diagrams obtained from materials testing are used, certain adjustments may be required. But they are not so very numerous and they are not so very significant.

There emerges an opportunity to resolve problems that with the methods that were used so far could not be resolved at all.

During the calculation, the curvilinear diagram may be modified and through it we may assess the influence on the calculation results of the *scaling factor, stress gradient, and stress creep.*

The possibility in the ZI methodology to use not only curvilinear stress-strain interdependencies but also other methods, enables comparison of results obtained by this method with results obtained by other methods. And there is more to it than that. Results obtained by other methods may be used, among other things, to improve the ZI methodology.

Since in the calculations of engineering structures, of utmost importance (even though it is a quite complex problem) is the calculation of the actual position of the neutral axis of the structural member, below we shall dwell on it somewhat longer. This problem was resolved i the ZI methodology. To this problem the *third* equation and the *fourth* equation are dedicated.

The first equation is the equation of static equilibrium of projections of axial forces.

The second equation is the equation of static equilibrium of the bending moments.

The third equation is a general equation derived from the first and the second equations.

The fourth equation is the third equation that was adapted for the direct calculation (without approximation cycles).

The importance and the purposes of the *third* and *fourth equations* are the same. Therefore, below, we keep mentioning the third equation in present paper.

The core of the ZI methodology and computational methods consists of *the first two equations* and *the third equation* derived from them, so the present article supplies more information about it.

15. The importance and the purpose of the *third* equation (the monographs par. 2.3)

Lithuania's mandatory Technical Regulation of Construction [STR 2.05.05:2005] uses for the calculation of the position of the neutral axis (the value ξ) an experimental equation. Of course, it is also appropriate for the cases that were tested and the test data were used to develop the equation. This is a flaw of the experimental equation. In addition to that, the equation was obtained from short-term tests and is quite complex. In order to obtain the equation, a radically simplified rectangular diagram of the stress distribution element in the compression zone was used. The stresses of the concrete tension zone are ignored. As a result, not real, but rather relative values of ξ are obtained. In the Eurocode methodology, the role of the third equation is performed by the linear interdependence – the Bernoulli flat sections hypothesis. In addition to that, also the Eurocode methodology adopts simplified calculation schemes.

Eurocodes contain equations for a curvilinear compression zone concrete stress diagram, but there is no methodology for its application. In the ZI method, it is possible to assume not just somewhat more realistic stress diagrams, but it also can be accounted for the deviations from the flat sections hypothesis. There is a theoretical possibility to examine the influence of scaling on the calculation results.

After the insertion into the ZI equations of certain values of coefficients, the equations become applicable to both elastic plastic and elastic materials: concrete, plastic, wood, metal, etc.

16. The main advantages of the *three* equations system and possibilities of its use (the monographs par. 2.5):

1. The equations of the ZI method of the ZI methodology are theoretical equations. Tests are only required to obtain materials $\sigma-\varepsilon$ diagrams and to verify the theoretical claims.
2. The value of each parameter of the perpendicular section is calculated separately (rather than performing a calculation of a sum of the values of two or more parameters).
3. And the values for each individual parameter that are calculated are not merely conditional, but they rather are the real values of each individual parameter.
4. *The ZI method is quite universal within the scope attributable to it.*
5. *The equations designed for the calculation by the ZI method of heavily reinforced members may be also used to solve a variety of other problems, such as:*
   1) the problem of the calculation of the beam structural member subject to the use situation bending moment M_{Ek} stress-stain state parameters at the crack (Section B.6.1, Annex D);
   2) the problem of the calculation of the rational reinforcement prestress, i.e. such a stress so that when $M_{Ed} \le M_{Rd}$ moment acts, we would have the desired aggregate stress value of the reinforcement $\sigma_S = \sigma_p + \Delta\sigma_{s,d}$ (Section B.6.2).
6. The ZI method is based on the basic content of the subjects taught to students of technology-related programmes, only instead of elastic materials equations here we have equations of elastic plastic materials that were derived. The equations of the ZI method are an extension of the range of the widely used resilient materials equations that are suitable not only for elastic materials but also for elastic plastic materials. When in the ZI equations respective values (ones, zeros) of some coefficients are inserted, in some cases equations of elastic materials are obtained. Even though the ZI method is quite universal (enables solving quite a few problems), it is also relatively uncomplicated and it can be understood and used by individuals with a basic background knowledge of technical curriculum subjects taught at universities (i.e. subjects of theoretical and structural mechanics and materials resistance).
7. In certain cases that are fairly common, from the general equations that in the general case use the approximation method we can get direct calculation equations (without sequential approximation) [Židonis 2009; Židonis 2010b; Židonis 2012]. But using them is not always worthwhile. For example, when it is not necessary to take into account the concrete in tension over the crack, the iterative method is simpler to use. In example F.4 of monographs [1 and 2], concrete in tension above the crack is taken into account. In the first approximation cycle, the thickness of the structural member's compression zone, which was calculated from equation (3.156), is equal to 8.09 cm. When the concrete in tension above the crack is not taken into account, a simpler equation (2.106) may be used to calculate the thickness of the compression zone of the member. The result is equal to 8.00 cm. Besides, this shows how little the thickness of the compressed zone can be influenced by the taking into account of the concrete in tension above the crack and how any such omission of taking it into account simplifies the entire calculation.
8. According to the equations of chapter 2 of monographs [1 and 2] we can estimate impact of concrete in tension in members without cracks or we may calculate at cross-sections at the crack when the performance of concrete in tension is not taken into account. In order to estimate the impact of the concrete over the crack, it is necessary to make the calculation with the help of equations of chapter 3 of monographs [1 and 2] – see example F.4 of the monographs. The impact of concrete in tension over the crack may also be estimated by calculating with the help of equations of chapter 2 of monographs [1 and 2]. However, in this case in equations of chapter 2 it is necessary to use the following recommendation that was supplied in chapter 3: in equations ω_{nt} has to be multiplied by $\eta_{tu\varepsilon}^2$, and ω_{mt} has to be multiplied by $\eta_{tu\varepsilon}^3$, and parameter $d_u = x_{tu} - x_w = h$ has to be substituted by parameter a_ε; it is advisable to assume $a_\varepsilon = 0$, thus simpler equations are obtained. $\eta_{tu\varepsilon} = \varepsilon_{0tu}/\varepsilon_{0\varepsilon}$. For instance, when calculating in this way problem F.4 of monographs [1 and 2] according to equations of chapter 2 the same result is obtained as the one that was obtained when carrying out the calculation in accordance with the equations of chapter 3. The calculation in accordance with equations of chapter 2 is even simpler than the one that is carried out in accordance with the equations of chapter 3.
9. Via the stress-strain diagram it is possible to assess the influence of scaling and stress gradient on the calculation results.

10. The ZI method can be used to solve the reverse problem, where based on the experimental parameters of perpendicular cracks (the height, width, and spacing) we may determine the stress-strain state of a member [Жидонис et al.1981].
11. The ZI method can be used as a benchmark for the development and testing of simplified computational methods.

17. Key results of the research (see chapter 4 of the monographs**)**

Below we present the key scientific research results of the ZI methodology and methods published various publications.

Key results of the scientific research of the author of the ZI methodology:

1. A mathematical model (equations and methodology) were prepared for describing the curvilinear relationships of stresses σ and strains ε using easy-to-integrate polynomials (multi-degree polynomials).

2. Two variants of the ZI method's *mathematical model* were prepared (a – the consecutive approximation model and b – the direct computation model) and three variants of the method's equations (the consecutive approximation equations; the more general equations of direct computation using the 5th order equation of σ– ε and somewhat simpler equations of direct calculation using the 3rd order σ - ε equation; i.e. the second version of the mathematical model contains two variants of equations):

3. A vast number of experimental tests and theoretical analyses of reinforced concrete and concrete beams that were performed. They confirm the suitability of the proposed method. [Жидонис 1973, 1980b, 1984, 1985, 1987, 1989, 1995; Жидонис, Мелис 1980, 1981; Жидонис, Ругенюс 1980; Жидонис, Ругенюс, Мелис 1980; Жидонис И., Жидонис А., Йокубайтис 1981; etc.; *zidonis.su.lt*].

18. The main conclusions of the ZI methodology (see chapter 4 of the monographs)

Here we present the man findings of the ZI methodology and methods published in various publications.

1. The ZI methodology developed by the author and easy-to-integrate equations for the description of stress-strain interrelationships of various elastic plastic materials were presented by the author. The equations are well suited to replace the usual stress-strain curvilinear interdependence of the Eurocode for concrete in compression with an easy-to-integrate polynomial.

2. When it comes to describing the "upward slope" section of the stress-strain interdependence, a simple 3rd degree interdependence is handy. In some individual cases, this interdependency satisfactorily describes the part of the "downward slope" interval that we are interested in.

3. When it is necessary to describe not only the upward-slope section of the stress-strain interdependency, but also the entire upward-slope section, a 5th degree interdependency is well fit for this purpose.

4. A method was proposed to increase the reliability of the stress-strain interdependence curvilinear diagram for concrete in compression of Eurocode in the ZI methodology from 50 % to 95 % and ~100 %.

5. When calculating the strength of structural members in bending, resorting to the curvilinear compressive zone stress diagram for concrete as described by the ZI method instead of the as a rule assumed conditional rectangular diagram is logical and uncomplicated.

6. When calculating by the ZI method the strength of amply reinforced concrete members, it is no longer necessary to have the maximum thickness parameter of the zone in compression calculated from the test equation.

7. The successive approximation-based (iterative) uniform ZI methodology that is presented is quite universal and gives a possibility (when curvilinear stress diagrams are used) to calculate the real rather than conditional values of parameters of materials strain and stress, tensile and compressive zone height, and crack height. Values that are calculated are not sum total values of two or more parameters but rather the values of each parameter that is calculated separately. This allows one to examine the influence of each parameter on the values of other parameters.

8. From the most general (but also the most complex) equations, it is easy to obtain simpler equations for the most common cases met in practice – for the calculation of the two-tee, tee, rectangular cross-sectional members subject to bending moments and axial forces.

9. The materials of the edges of the structural members with shelves and the material of the shelves may be either different or the same. The equations of the second case are simpler.

10. For the calculation, it is only necessary to have the stress-strain diagrams.

11. Instead of using curvilinear diagrams one may also use non-curvilinear (triangular, rectangular) diagrams or "stiff" curvilinear diagrams or other stress diagrams, and it is possible to disregard the stresses (such as the ones of the tensile zone) altogether.

12. The methodology and the equations are also applicable to the case of the calculation of elastic materials (triangular stress diagrams are used).

13. The structural members may be of any cross-sectional shape, unreinforced or variously reinforced with pre-stressed, tensioned or mixed reinforcement at any point in the height of the structural member, they may be of concrete, reinforced concrete, wood, metal, etc., they may be layered, with cracks or without cracks.

14. It is possible to make the calculation at cross-sections without cracks, at the cracks, between the cracks. Any stage of loading can be considered, including the stage of loss of bearing capacity in the elasticity hinges.

15. It is possible to take into account the displacement of the cross-sectional layers in respect of each other, i.e. materials strain deviation from the strain obtained using the flat section hypothesis.

16. A very important and complex problem of determining the real position of the neutral axis has been solved. In the ZI method, the position of the neutral axis may be calculated *theoretically* even when only the bending moment and / or axial force values are known but

no strain value is known in advance. This is very important when the structures are subjected to constant loads, since, at present, for this purpose either empirical equations are used or the calculations that are made are very inaccurate (are very approximate).

17. In the general case, the calculation is made by consistent approximation method (iterative method). However, exceptions are also possible. Direct calculation (without any approximation cycles) is also possible. For example, when the parameters of the element stress diagram are known $\nu = const$, $\omega_n = const$ and $\omega_m = const,$ it is not necessary to repeat the calculations.

18. The ZI method is kind of a further development of A. Rosenblumas' theory. The aforesaid A Rosenblumas' theory is only applicable until the continuous loading (use) situation. The ZI methodology covers the entire possible loading range from the very start of loading to the failure of the member. In addition to that, the ZI method allows for the application of a wider variety of material stress diagrams. In the methods of A. Rosenblumas' theory and the European regulations, in the section at the crack, we deal with the calculation of stresses of the outermost layers in the compression zone of concrete. In order to calculate the curvature, we have to know the strains. The strains are calculated by dividing the stresses by the strain modulus. But its meaning is unknown. The module shall be selected so that the calculation results are as close as possible to the test results. There is no such problem in the ZI methodology – the strains are calculated;

19. A. Rosenblumas' equations have been verified by testing (also by the author). Therefore, the equations of the ZI method may be also considered to have been verified in this range of loading. The results obtained by conventional experimental test-based methods and the results obtained by the ZI method are close. This means that the ZI method is real. It may be argued that the ZI method has already been partially verified by tests because the curvilinear diagram had been employed in other papers of the author [Жидонис 1973, 1974, 1985, 1987, 1988, 1989, 1995, etc.].

20. The basics of the ZI method are already in place. The method may already at this point in time be used for certain practical purposes (e.g. calculation of strength of members subject to bending) and for various theoretical research studies. The main purpose of presenting the ZI method in the monograph is to publish a mathematical model so that it can be used now, without further delay. Given the versatility of the method, the feasibility of the method for practical purposes needs to be further researched in the future. The next step that is required is computerisation of the ZI method. Computerisation would allow an amount of theoretical research to be carried out with low investment of time and effort. large A number of additional experimental research studies are necessary, but this is topic will have to be covered by further scientific research work.

21. The methodology and the equations presented by ZI methodology enable to make the calculation by the ZI method of the values of the stress-strain state parameters of structural members without cracks and the ones with cracks at normal sections *directly* (without any sequential approximation cycles) even in the case where one does not know in advance and when one has the changing values of ν, ω_n and ω_m $(\nu \neq const, \omega_n \neq const,$ and $\omega_m \neq const)$.

22. The members may be layered (Fig. 1, 2.2, 2.3), they may have a rectangular cross-section, they may be with shelves, they may be made of concrete, reinforced concrete, wood, metal, etc. The materials of the component parts may be different: the edges may be of one material, while the shelves may be made of a different material, the reinforcements (the weakenings) may be made of a still different material, the reinforcements may be made still of a fourth material. The reinforcement may be concentrated not merely at the edges of the zones in tension or in compression, but may also be located anywhere within the height of the element's tensile and compressive zone. It may be tensioned, pre-stressed or mixed. It is possible to take into account the deviation of the reinforcement strains from the strains consistent with the flat sections (Bernoulli) hypothesis.

23. It is possible to use realistic curvilinear material stress diagrams, therefore the calculated values of the parameters (compressive and tensile zone height, crack height (depth), material strain and stress, etc.) are real, and they are not conditional and they are not integrated (not aggregate).

24. By selecting the strain of any one layer of the material (e.g. strain of the compressive or tensile zone concrete or of the reinforcement) it is possible to calculate the cracking moment, the stress-strain state parameters at cross-sections between the cracks or at the crack the height of which is known in advance, to calculate the values of the breaking moment and of the longitudinal force or the reinforcement (the reinforcement's cross-sectional area).

25. It is possible to use not merely curvilinear diagrams, but also diagrams of other shapes (rectangular, triangular) or "stiff" curves with constant ω_n and ω_m and other parameters. The stresses may be also ignored.

26. Since in the ZI methodology bending moments are assumed around any $a-a$ axis located at a distance a_a from the $w-w$ axis, it is therefore possible, when solving a specific problem, to choose the best location for this axis and simplify the calculation.

27. When making static equilibrium equations for bending moments, a simpler version is usually obtained by assuming moments around the $w-w$ axis, located at the member's edge that is in compression, and $\varepsilon_\varepsilon = \varepsilon_w$

28. The ZI methodology is suitable for calculating various parameters of structural members at any loading stage.

29. When using the 5th degree (often even the 3rd degree) stress equations, it is possible to calculate even the parameters of uncut beams with multiple supports at hinges at the stage of the decreasing bending moments.

30. When material stresses do not exceed the maximum values (do not exceed the material strength), i.e. strains do not exceed the corresponding extreme stress values, for example, in the building operation phase (permanent state), a simpler stress dependence of the 3rd degree may be used, since in both cases the "upward slope" sections of the stress-strain graph do not differ much. This simplifies the

equations of the ZI method. In this variant, in individual cases, the "downward slope" part of the graph may also be used, but, in the particular case, it needs to be verified.

31. When no strain value of any layer is known in advance (then the external loads and their effects are known – M, N) to calculate the position of the neutral axis, it is appropriate to use the *third* static equilibrium equation. But there, if an adjustment of ε_w is required and $\eta_{0\varepsilon} = \varepsilon_{0\varepsilon} / \varepsilon_{0cm} = \varepsilon_w / \varepsilon_{0cm} \neq const,$ the computation needs to be repeated.

32. In a general case, direct computation is possible when the strain value of any of the layers is known in advance. In the case of structural members with shelves, it is necessary to know in advance as to whether the shelf is in compression or in tension. It is also necessary to know which reinforcement is in the tensile zone and which one is in the compressive zone. In other cases, the calculations need to be repeated.

33. In the direct calculation, the variable distribution of stresses at shelf edges (cantilever overhangs) may be calculated in two ways: (1) in a somewhat more accurate but also the more sophisticated way, by assuming the actual stress distribution in the cantilever overhangs or (2) in a somewhat more approximate but simpler way, by assuming the actual stress value only at the centre of the cantilever overhangs or at another selected point; such stresses shall also be assumed over the entire area of the cantilever overhangs; and the desired accuracy can be achieved by dividing the cantilever overhangs areas into smaller areas and by applying the above rule to them.

34. The equations of the ZI method are kind of an expansion of the possibilities of the traditional elastic materials resistance equations–and they are also applicable to the case of elastic plastic materials. In some individual cases, the equations for elastic materials happen to be a simpler case of the equations derived by the author of the present paper.

35. The examples of the application the ZI method already at this point in time enables solving quite a few practical problems.

36. For the calculation of the strength of beams and columns according to the curvilinear Eurocode concrete stress diagram, it is possible to use the general ZI method for calculating the strength of beams and columns.

37. Member strength calculations by the ZI method according to the Eurocode curvilinear stress diagram for concrete, where the entire cross-section is in compression, is a more logical solution than the traditional methods because the concept of compressive strength limit (that is not in all cases logical) is not used.

38. The ZI method opens up possibilities for multiple prospective research studies. For example, to study the inverse problem, i.e. when the stress-strain state parameters are calculated from the crack parameters measured in nature (crack height, width and distance between cracks) [Жидонис И., Жидонис А., Йокубайтис 1981; *zidonis.su.lt*]. Research whether or not the stress-strain diagram may be used to estimate the materials creep strains and, if so, how can such estimate be made. The ZI methodology enables research of values of parameters of scale [Жидонис, Мелис 1981; Жидонис И.Ю. 1984] and stress gradient 's [Жидонис 1982a] impact on the stress diagram and on the values of the parameters under calculation. These are but a few examples of possible prospective research topics.

19. *The main conclusion of the* ZI methodology

The ZI methodology presents an alternative to other methodologies that are currently most frequently used for similar purposes. It has a broader application scope and potential than other analogous methodologies that were mentioned here. *The ZI methodology* is more versatile that others. It is suitable for the full range of possible acting forces. The results of the calculations are more realistic and more accurate. *The ZI methodology* within the scope of its application could replace the entire group of current methodology equations by just *two equations*. From these two equations, all the equations of the methods of the ZI methodology are derived.

20. Summary

The paper presents a concise summary of the main findings of the ZI methodology and methods posted in various publications.

1. A *methodology has been developed* and easy-to-integrate *equations* for the description of various curvilinear stress-strain interdependences.
2. *Quite universal* iterative and direct calculation *methods have been developed to calculate the stress-strain state* in perpendicular sections of beam members directly taking into account the actual strain properties of the materials. In the section at the crack, the calculation deals with the *strains* of the concrete in the outermost layer of the compression zone required to calculate the curvatures, *but not the stresses*. Currently, the European regulations and prof. A. Rosenblumas' methodology uses calculation of the *stresses*, *but not of the strains*. The strains are calculated by dividing the stresses by the strain modulus. But its meaning is unknown. This is a problem. It is necessary to *select such modules* so that the calculation results are as close as possible to the test results. In the ZI methodology, by contrast, both the strains and the stresses are calculated. There is no need to guess the modules. In this aspect the ZI methodology fundamentally differs from prof. A. Rosenblumas' methodology.
3. *Practical variants of the direct calculation method have been developed* to calculate the stress-strain state of perpendicular sections (cross-sections) of beam members that directly take into account the materials' actual strain properties.
4. A vast number of rather complex tests have been carried out to test the theoretical methods; their findings validate the theoretical propositions.
5. *The methods that were developed are applicable not only for the calculations of members of concrete and variously reinforced concrete, but also for the ones made of other materials (wood, plastic, metal, etc.)*
6. Since the methodology *employs real* stress-strain *interdependences*, consequently, the values of the

calculated parameters (crack height, height of the compression and tension zone, strain and stress) are also *real*.

7. In the method's variants that were developed, for the sake of comparison, *it is also possible to assume stress diagrams of other kinds* (triangular, rectangular or other).
8. The proposed *methods* extend the possibilities of the elastic materials calculation methodology: *they are suitable for calculations not only in the case of elastic materials but also in the case when the materials are non-elastic.*
9. Even though the *variants of the ZI method are rather universal, at the same time they are relatively uncomplicated*; to be able to understand and use them, it is sufficient to have the knowledge of subjects that are usually taught to all technology students.
10. The *variants of the ZI method* that were developed, already now, at this point in time, may be used for the aforementioned calculations and *for further research*, e.g. to research stress-strain state of structures according to the measured crack parameters, to improve deflection prediction methods, calculation of resistance of structures, etc.
11. The variants of stress-strain curvilinear diagrams of the regulation [3] that are presented have the reliability not only 50%, but also 95% and ~ 100%.
12. The method for calculating the strength of heavily reinforced beams that has been proposed by the author does not require any advance knowledge of the maximum thickness of the compression zone, consequently, neither does it require any advance knowledge of the maximum strength (3).
13. For the calculation of the strength of beams and columns according to the curvilinear Eurocode's concrete stress diagram, it is possible to use the general ZI method for calculating the strength of beams and columns. The calculation of strength of structural members according to the Eurocode's curvilinear stress diagram for concrete, in cases where the entire cross-section is in compression, would be a more logical solution than the traditional methods because the concept of compressive strength limit value (that is not in all cases logical) is not used in this case.
14. The most important means to facilitate the employment of the ZI method would be the development of a possibly simpler way of the solution of the multi-step equation and the preparation of programs for solving the problems of the ZI method.

Literature

1. Židonis I. 2018 a. The ZI Method and its Application for Calculating of Stress-Strain Parameters of Structural Members. Monograph. ISBN 978-3-11-062778-7. Klaipeda University. Sciendo, 564 p. https://www.degruyter.com/view/product/512877.
2. Židonis I. 2018 b. ZI metodas ir jo panaudojimas konstrukcinių elementų įtempių-deformacijų būvio parametrams apskaičiuoti (The ZI Method and its Use for the Calculation of Stress-strain Parameters of Structural Members). Monografija, ISBN 978-609-481-010-7. Klaipėdos universitetas: Klaipėdos universiteto leidykla, 557 p.
   May be procured online: https://www.ku.lt/leidykla/turinys/leidiniai/laisvai-prieinami-leidiniai/zi-metodas-ir-jo-panaudojimas-konstrukciniu-elementu-itempiu-deformaciju-buvio-parametrams-apskaiciuoti/
3. Židonis I. 2019. Curvilinear stress-strain relationship for concrete of EN-2 regulation in the ZI Method and the calculation of beam strength. ISSN 1392-1207. Mechanika. Volume 25(5): 341-349.
4. EN 1992-1-1. Eurocode 2: Design of concrete structures. Part 1-1: General rules and rules for buildings. Brussels, 2004. 225 p.
5. STR 2.05.05:2005. Design of concrete and reinforced constructions. Vilnius: Rekona, 2005. 123p. (in Lithuanian).
6. LST EN 1992-1-1:2005. Eurocode 2. Design of concrete structures. Part 1-1: General rules and rules for buildings. Vilnius: Rekona, 2005. -232p. (in Lithuanian).

The summary reflects not only the essence of the article but it also reflects the essence of the entire ZI methodology.

Ipolitas Židonis

ZI METHODOLOGY AND ZI METHOD:

AN O V E R V I E W

S u m m a r y

The article reviews both the ZI methodology developed by the author of the present article and the ZI *method*, a means for the implementation of the rules of the methodology. The scope of the ZI methodology and the ZI method comprises the calculation of the real values of the parameters of structural members subjected to axial forces and bending moments at normal sections. The properties and the field of the possibilities of application of the ZI methodology (and the ZI method) are compared with the ones of other similar methodologies (and methods) currently employed for analogous purposes. The article demonstrates that the ZI methodology (and the ZI methods) have obvious advantages over the other applicable methods that are currently in use.

Keywords: ZI *methodology*, ZI *calculation methods, beam type members, columns, normal sections, strain, stress, stress diagrams, curvilinear stress diagrams, stress-strain state, crack height, concrete, reinforced concrete, material of structural members, reinforcement, regulations for calculating structures*.

September 20, 2019