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ГИПОТЕЗЫ О ДЕПЛАНАЦИИ СЕЧЕНИЯ ОТ ДЕФОРМАЦИЙ СДВИГА В ЖЕЛЕЗОБЕТОННЫХ КОНСТРУКЦИЯХ, ИСПЫТЫВАЮЩИХ КРУЧЕНИЕ С ИЗГИБОМ

Аннотация. В статье проведен анализ гипотез о депланации угловых деформаций в железобетонных конструкциях при изгибе с кручением. Рассмотрен простой способ из семейства метод сеток для аппроксимации деформаций сложных функций при рассматриваемом сложном напряженном состоянии. Построены и проанализированы эпюры угловых и линейных деформаций в таких конструкции для нахождения этих деформаций, изгибающих и крутящих моментов воспринимаемых бетоном сжатой области с использованием принятых гипотез и коэффициентов для проецирования нормальных и касательных напряжений (деформаций) посредством диаграмм сжатого бетона и рабочей арматуры. Аппроксимацией расчетного сечения малыми квадратами построена пространственная поверхность деформаций, с соответствующими градиентами этих деформаций в сечении с трещиной и на этой основе записаны выражения для суммарных продольных деформаций и деформаций сдвига в сечении элемента при изгибе с кручением. С использованием мембранной аналогии функций напряжений Тимошенко-Гудьера и предложенного варианта новых сложных функций из семейства метода сеток проведен анализ погрешности нахождении значения сложных функций в рассмотренных характерных точках (2%) и в любых точках поперечного сечения (7%).

Использование предложенных гипотез и приведенного варианта сложных функций позволяет учитывать депланацию сложнонапряженного сечения железобетонного элемента с трещинами, испытывающего изгиб с кручением.

Ключевые слова: билинейная поверхность, опасная пространственная трещина, деформационный эффект железобетона, депланация, градиент, векторы, фибры, форма эпюры.

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DEPLANATION HYPOTHESES FOR ANGULAR DEFORMATIONS IN REINFORCED CONCRETE STRUCTURES UNDER COMBINED TORSION AND BENDING

Abstract. The article analyzes the hypothesis of deplanation of angular deformations in reinforced concrete structures during bending with torsion. A simple method from the field of the grid methods for approximating the deformations of complex functions under the 3D stress state is considered. Diagrams of angular and linear deformations in such structures were built and analyzed to find these deformations, bending and torques perceived by the concrete of the compressed area using the accepted hypotheses and coefficients for projecting normal and shear stresses (strains) through diagrams of compressed concrete and working reinforcement. Approximating the calculated section by small squares, a spatial surface of deformations was constructed. This is with the corresponding gradients of these deformations in the section with a crack, and on this basis, expressions were written for the total longitudinal deformations in the section and shear deformations in the section of the element during bending with torsion. Using the membrane analogy of the Timoshenko-Goodyear stress

functions and the proposed version of new complex functions from the field of the grid method, an analysis was made of its error, when we find the value of complex functions at the considered characteristic points (2%) and at any points of the cross section (7%).

The use of the proposed hypotheses and the given version of complex functions makes it possible considering the warping of the 3D stressed section of a reinforced concrete element with cracks undergoing bending with torsion.

Keywords: *bilinear surface, dangerous spatial crack, deformation effect of reinforced concrete, deplanation, delta jump functions, vectors, fibers.*

СПИСОК ЛИТЕРАТУРЫ

1. Бондаренко В.М., Колчунов. Вл.И. Расчетные модели силового сопротивления железобетона. М.: АСВ, 2004. 472 с.

2. Верюжский Ю.В., Голышев А.Б., Колчунов Вл.И., Клюева Н.В., Лисицин Б.М., Машков И.Л., Яковенко И.А. Справочное пособие по строительной механике. В двух томах.: Учебное пособие. М.: Изд-во АСВ, 2014. 432 с.

3. Голышев А.Б., Колчунов. Вл.И. Сопротивление железобетона. К.: Основа. 2009. 432 с.

4. Голышев А.Б., Колчунов. Вл.И., Яковенко И.А. Сопротивление железобетонных конструкций, зданий и сооружений, возводимых в сложных инженерно-геологических условиях. К.: «Талком», 2015. 371 с.

5. Колчунов Вл.И., Федоров В.С. Понятийная иерархия моделей в теории сопротивления строительных конструкций // Промышленное и гражданское строительство. 2020. №8. С. 16–23. https://doi.org/10.33622/0869-7019.2020.08.16-23.

6. Колчунов Вл. И., Демьянов А. И., Протченко М. В. Моменты в железобетонных конструкциях при изгибе с кручением // Строительство и реконструкция. 2021. № 3(95). С. 27-46. http://doi.org/10.33979/2073-7416-2021-95-3-27-46.

7. Kolchunov Vl., Dem'yanov A., Protchenko M. The new hypothesis angular deformation and filling of diagrams in bending with torsion in reinforced concrete structures. Journal of Applied Engineering Science. 2022, Vol.19(4). Pp. 972-979, http://doi.org/10.5937/jaes0-32660

8. Kolchunov V., Demyanov A., Shankov V., Grichishnikov S. The New Linear Deformations Hypothesis of Reinforced Concrete Under Combined Torsion and Bending. Proceedings of MPCPE 2021. Lecture Notes in Civil Engineering, Vol. 182. https://doi.org/10.1007/978-3-030-85236-8_9

9. Kolchunov V., Dem'yanov A., Naumov N. Analysis of the "nagel effect" in reinforced concrete structures under torsion with bending. IOP Conference Series: Materials Science and Engineering. 2020. Pp. 953.

10. Karpenko N.I., Kolchunov Vl.I., Travush V.I. Calculation model of a complex stress reinforced concrete element of a boxed section during torsion with bending // Russian Journal of Building Construction and Architecture. 2021. №3(51). Pp. 7-26. https://doi.org/ 10.36622/VSTU.2021.51.3.001.

11. Kim C., Kim S., Kim K.-H., Shin D., Haroon M., Lee J.-Y.: Torsional Behavior of Reinforced Concrete Beams with High-Strength Steel Bars. ACI Struct. J. 116, 251-233 (2019). https://doi.org/10.14359/51718014.

12. Bernardo L.: Modeling the Full Behavior of Reinforced Concrete Flanged Beams under Torsion. Appl. Sci. 9, 2730 (2019). https://doi.org/10.3390/app9132730.

13. Lin W. Experimental investigation on composite beams under combined negative bending and torsional moments. Advances in Structural Engineering, 24(6), 1456–1465 (2021). https://doi.org/ 10.1177/1369433220981660.

14. Křístek V., Průša J., Vítek J.L. Torsion of Reinforced Concrete Structural Members // Solid State Phenomena 2018. Vol. 272. Pp. 178-184. http://doi.org/10.4028/www.scientific.net/ SSP.272.178.

15. Santhakumar R., Dhanaraj R., Chandrasekaran E. Behaviour of retrofitted reinforced concrete beams under combined bending and torsion: A numerical study. Electronic Journal of Structural Engineering. 2007. No. 7. Pp. 1–7.

16. Kalkan I., Kartal S. Torsional Rigidities of Reinforced Concrete Beams Subjected to Elastic Lateral Torsional Buckling. International Journal of Civil and Environmental Engineering. 2017. Vol. 11. No.7. Pp. 969–972.

17. Bernardo L. Modeling the Full Behavior of Reinforced Concrete Flanged Beams under Torsion. Applied Sciences. 2019. Vol. 9(13). p. 2750. http://doi.org/10.3390/app9132730.

18. Nahvi H., Jabbari M. Crack detection in beams using experimental modal data and finite element model. International Journal of Mechanical Sciences. 2005. Vol. 47. Pp.1477-1497.

19. Vishnu H. Jariwalaa, Paresh V. Patel, Sharadkumar P. Purohit. Strengthening of RC Beams subjected to Combined Torsion and Bending with GFRP Composites. Procedia Engineering. 2013. Vol. 51. Pp. 282–289.

20. Tsai H.-C., Liao M.-C. Modeling Torsional Strength of Reinforced Concrete Beams using Genetic Programming Polynomials with Building Codes. KSCE Journal of Civil Engineering. 2019. Vol. 23. Pp. 3464–3475. http://doi.org/10.1007/s12205-019-1292-7.

REFERENCES

1. Bondarenko V.M., Kolchunov. Vl.I. Calculation models of the force resistance of reinforced concrete. M.: ASV, 2004. 472 p.
2. Veryuzhsky Yu.V., Golyshev A.B., Kolchunov Vl.I., Klyueva N.V., Lisitsin B.M., Mashkov I.L., Yakovenko I.A. Reference manual on structural mechanics. In two volumes.: Textbook. M.: ASV, 2014. 432 p.
3. Golyshev A.B., Kolchunov. Vl.I. Reinforced concrete resistance. K: Osnova. 2009. 432 p.
4. Golyshev A.B., Kolchunov. Vl.I., Yakovenko I.A. Resistance of reinforced concrete structures, buildings and structures erected in difficult engineering and geological conditions. K.: Talcom, 2015. 371 p.
5. Колчунов Вл. И., Федоров В.С. Conceptual hierarchy of models in the theory of resistance of building structur. Industrial and civil engineering. 2020. №8. Pp. 16–23. https://doi.org/10.33622/0869-7019.2020.08.16-23.
6. Kolchunov V.I., Demyanov A.I., Protchenko M.V. Moments in reinforced concrete structures under bending with torsion. *Building and Reconstruction*. 2021; (3): 27-46. (In Russ.) https://doi.org/10.33979/2073-7416-2021-95-3-27-46
7. Kolchunov Vl., Dem'yanov A., Protchenko M., The new hypothesis angular deformation and filling of diagrams in bending with torsion in reinforced concrete structures // Journal of Applied Engineering Science. 2022. Vol.19(4). Pp. 972-979. http://doi.org/10.5937/jaes0-32660
8. Kolchunov V., Demyanov A., Shankov V., Grichishnikov S. The New Linear Deformations Hypothesis of Reinforced Concrete Under Combined Torsion and Bending. Proceedings of MPCPE 2021. Lecture Notes in Civil Engineering, Vol. 182. https://doi.org/10.1007/978-3-030-85236-8_9
9. Kolchunov V., Dem'yanov A., Naumov N. Analysis of the "nagel effect" in reinforced concrete structures under torsion with bending. IOP Conference Series: Materials Science and Engineering. 2020. Pp. 953.
10. Karpenko N.I., Kolchunov Vl.I., Travush V.I. Calculation model of a complex stress reinforced concrete element of a boxed section during torsion with bending. Russian Journal of Building Construction and Architecture. 2021. №3(51). Pp. 7-26. https://doi.org/ 10.36622/VSTU.2021.51.3.001.
11. Kim C., Kim S., Kim K.-H., Shin D., Haroon M., Lee J.-Y.: Torsional Behavior of Reinforced Concrete Beams with High-Strength Steel Bars. ACI Struct. J. 116, 251-233 (2019). https://doi.org/10.14359/51718014.
12. Bernardo L.: Modeling the Full Behavior of Reinforced Concrete Flanged Beams under Torsion. Appl. Sci. 9, 2730 (2019). https://doi.org/10.3390/app9132730.
13. Lin W. Experimental investigation on composite beams under combined negative bending and torsional moments. Advances in Structural Engineering, 2021, 24(6), Pp. 1456–1465. https://doi.org/10.1177/1369433220981660.
14. Křístek V., Průša J., Vítek J.L. Torsion of Reinforced Concrete Structural Members // Solid State Phenomena 2018. Vol. 272. Pp. 178-184. http://doi.org/10.4028/www.scientific.net/ SSP.272.178.
15. Santhakumar R., Dhanaraj R., Chandrasekaran E. Behaviour of retrofitted reinforced concrete beams under combined bending and torsion: A numerical study. Electronic Journal of Structural Engineering. 2007. No. 7. Pp. 1–7.
16. Kalkan I., Kartal S. Torsional Rigidities of Reinforced Concrete Beams Subjected to Elastic Lateral Torsional Buckling. International Journal of Civil and Environmental Engineering. 2017. Vol. 11. No.7. Pp. 969–972.
17. Bernardo L. Modeling the Full Behavior of Reinforced Concrete Flanged Beams under Torsion. Applied Sciences. 2019. Vol. 9(13). p. 2750. http://doi.org/10.3390/app9132730.
18. Nahvi H., Jabbari M. Crack detection in beams using experimental modal data and finite element model. International Journal of Mechanical Sciences. 2005. Vol. 47. Pp.1477-1497.
19. Vishnu H. Jariwalaa, Paresh V. Patel, Sharadkumar P. Purohit. Strengthening of RC Beams subjected to Combined Torsion and Bending with GFRP Composites. Procedia Engineering. 2013. Vol. 51. Pp. 282–289.
20. Tsai H.-C., Liao M.-C. Modeling Torsional Strength of Reinforced Concrete Beams using Genetic Programming Polynomials with Building Codes. KSCE Journal of Civil Engineering. 2019. Vol. 23. Pp. 3464–3475. http://doi.org/10.1007/s12205-019-1292-7.

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