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Parametric Diagrams of Steel and Concrete Behavior in Finite Element Modeling

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INTRODUCTION & AIM

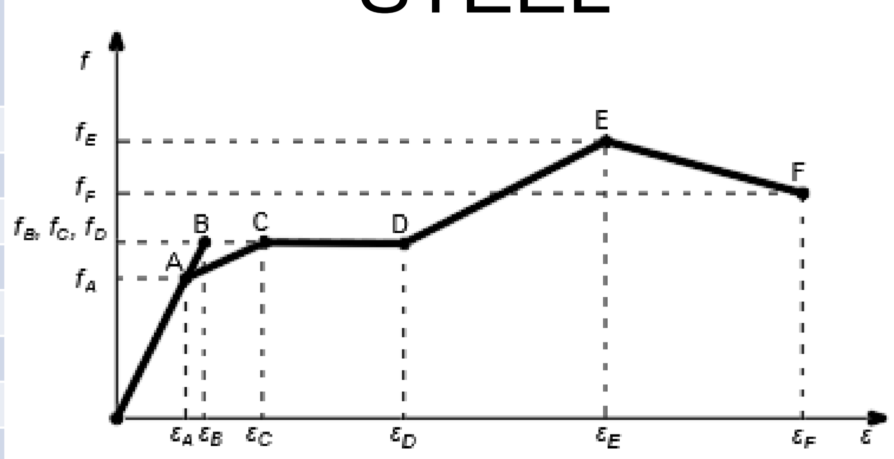
The most accurate setting of material behavior diagrams in finite element modeling (FEM) determines the accuracy of reproducing the real mechanism of structural failure under load. Therefore, the aim of the study was to find the optimal type of diagrams that would consider the nonlinear component and the peculiarities of National Standards.

METHOD

The study used statistical analysis of the steel design parameters of the most commonly used steel classes and the deformation-iteration method to determine the curve of dependence between stresses and strains in concrete, with control of the load-bearing capacity criteria at each stage of the calculations.

Diagram Parameter	Steel Grade		
	S235JR, S235J0, S235J2	S355J2, S355K2, S355N, S355NL, S355M, S355ML	S550Q, S550QL, S550QL1
ε_A	0,8	0,8	0,9
f_A	0,8	0,8	0,9
ε_C	1,7	1,7	1,7
f_B. f_C. f_D.	1	1	1
ε_D	14,0	16,0	18,0
ε_E	141,6	88,3	26,2
f_E	1,653	1,415	1,16
ε_F	251	153	51,1
f_F	1,35	1,26	1,10

STEEL



CONCRETE

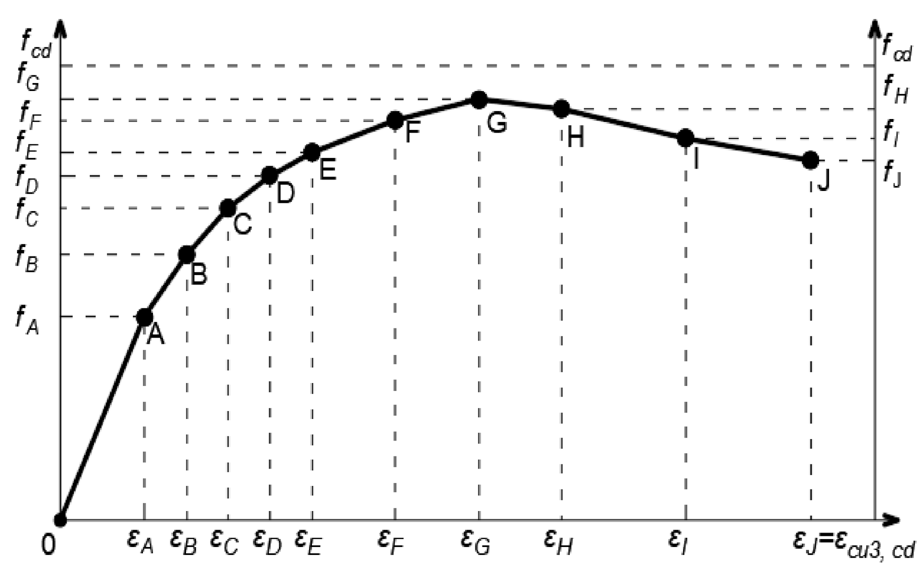
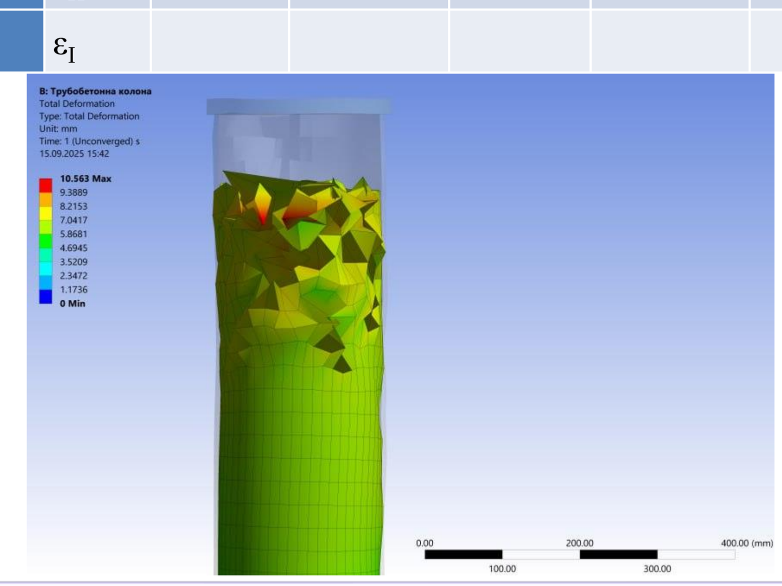


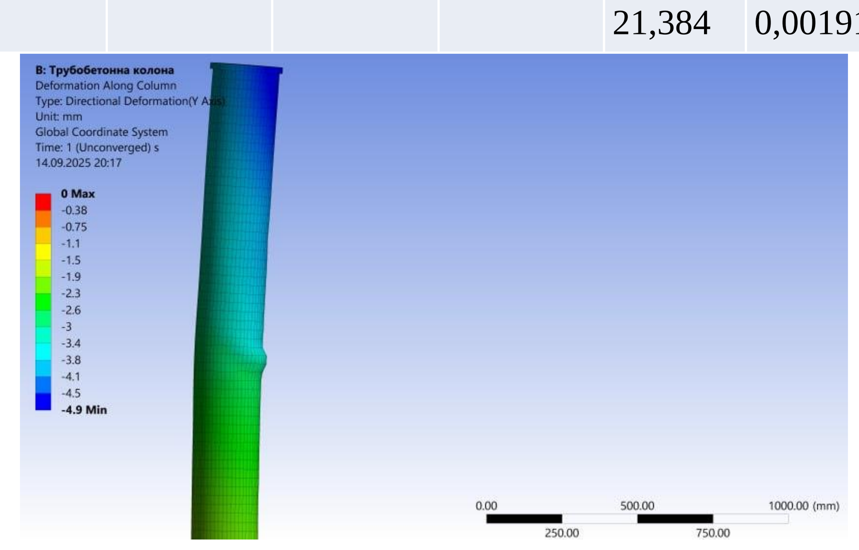
Diagram Parameter	C16/20	C20/25	C25/30	C30/35	C32/40
$f_{ck, cube}$ (MPa)	20	25	30	35	40
f_{cd} (MPa)	11,5	14,5	17	19,5	22
$\varepsilon_{cu3, cd}$ (‰)	3,23	3,1	3	2,8	2,64
f_A	0,498	0,454	0,415	0,379	0,344
ε_A	0,111	0,11	0,11	0,111	0,11
f_B	0,658	0,61	0,566	0,523	0,481
ε_B	0,167	0,168	0,163	0,168	0,167
f_C	0,775	0,729	0,685	0,641	0,595
ε_C	0,223	0,223	0,22	0,221	0,223
f_D	0,857	0,818	0,778	0,736	0,691
ε_D	0,279	0,277	0,273	0,279	0,277
f_E	0,914	0,883	0,849	0,812	0,77
ε_E	0,334	0,332	0,327	0,332	0,333
f_F	0,97	0,955	0,936	0,912	0,882
ε_F	0,446	0,445	0,437	0,443	0,443
f_G	0,986	0,98	0,972	0,961	0,944
ε_G	0,557	0,555	0,547	0,554	0,557
f_H	0,981	0,98	0,98	0,977	0,972
ε_H	0,666	0,665	0,657	0,664	0,667
f_I	0,95	0,952	0,959	0,966	0,972
ε_I	0,833	0,832	0,82	0,832	0,833
f_J	0,893	0,898	0,907	0,925	0,939
ε_J	1	1	1	1	1
E_{cd} (GPa)	20	23	25	27	28,5

RESULTS & DISCUSSION

When performing FEM of composite steel and concrete (CSC) structures in the ANSYS software package, it was found necessary to consider the plastic deformation in order to more accurately reflect the actual behavior of composite sections, based on the physical and mechanical properties of the materials, which would correlate with the current codes. As a result, parametric values of key points of the plastic section of the concrete performance diagram were obtained, which made it possible to simulate the post-critical stage of CSC columns under static and dynamic loads. The important aspect in CSC column modeling was to take into account the joint work of the concrete core and steel pipe from full sliding to rigid connection, as well as the point of compressive force application to the steel cap or concrete.

Diagram Parameter		C16/20		C20/25		C25/30		C30/35		C32/40	
$f_{ck, cube}$ (МПа)		20		25		30		35		40	
f_A	ε_A	5,728	0	6,586	0	7,057	0	7,392	0	7,569	0
f_B	ε_B	7,57	0,00018	8,85	0,00018	9,617	0,00016	10,202	0,00016	10,571	0,00015
f_C	ε_C	8,907	0,00036	10,573	0,00035	11,648	0,00033	12,505	0,00031	13,099	0,0003
f_D	ε_D	9,856	0,00054	11,862	0,00052	13,23	0,00049	14,363	0,00047	15,207	0,00044
f_E	ε_E	10,514	0,00072	12,803	0,00069	14,435	0,00065	15,834	0,00062	16,936	0,00059
f_F	ε_F	11,159	0,00108	13,845	0,00104	15,909	0,00098	17,787	0,00093	19,399	0,00088
f_G	ε_G	11,342	0,00144	14,211	0,00138	16,53	0,00131	18,738	0,00124	20,761	0,00118
f_H	ε_H					16,656	0,00164	19,061	0,00155	21,376	0,00147
f_I	ε_I									21,384	0,00191





CONCLUSION

The resulting diagrams provide an appropriate representation of the materials' nonlinear properties with an accuracy of 5-7% compared to experimental tests of similar structures, allowing for a correct assessment of limit states and optimal design decisions in terms of safety and cost-effectiveness.

FUTURE WORK / REFERENCES

Further research will help gather enough statistical data to train the neural network, which will make it way easier to check and evaluate the results of experiments on CSC structures.