Review Certificate

2024/4/9

To Whom It May Concern,
By this letter, I would like to explain the contributions of *Dr. DANIEL CHRISTIANTO* from *Tarumanagara University* as a Peer Reviewer of *The 7th International Conference on Material Strength and Applied Mechanics (MSAM 2024)* to be held in *Gyor, Hungary* during *29 July-1 August 2024*.

For each manuscript submitted to the Proceedings of the conference, it is required that at least two excellent reviewers who are not only competent in the technology but also are familiar with the existing literature. Their role is finally to determine if the submitted manuscript has a high scientific level and is worth publication.

Dr. DANIEL CHRISTIANTO has provided excellent feedback on the following article
Optimizing Elasto-Plastic Analysis of Concrete Beams Exposed to Fire: Incorporating the Influence of Concrete Cover
after carefully analyzing the merits of the paper with regards to scope, applications, research methodology, experimental techniques, and verification of mathematical equations, data interpretation, and grammar.

Dr. DANIEL CHRISTIANTO's substantial contributions to maintain the standards of the Conference are greatly appreciated.

Sincerely,

MSAM2024 Organizing Committee
msam@msamconf.org
www.msamconf.org

UNTAR Universitas Tarumanagara

UNTAR untuk INDONESIA

SURAT TUGAS
Nomor: 19-R/UNTAR/Pengabdian/VIII/2024

Rektor Universitas Tarumanagara, dengan ini menugaskan kepada saudara:

DANIEL CHRISTIANTO, S.T., M.T., Dr.

Untuk melaksanakan kegiatan pengabdian kepada masyarakat dengan data sebagai berikut:

Judul	:	reviewer artikel "Reviewer article "Optimizing Elasto-Plastic Analysis of Concrete Beams Exposed to Fire: Incorporating the Influence of Concrete Cover "
Mitra	:	The 7th International Conference on Material Strength and Applied Mechanics (MSAM 2024) to be held in Gyor
Periode	:	Januari sd Juli 2024
URL Repository	:	-

Demikian Surat Tugas ini dibuat, untuk dilaksanakan dengan sebaik-baiknya dan melaporkan hasil penugasan tersebut kepada Rektor Universitas Tarumanagara

11 Agustus 2024
Rektor

UNIVERSITAS TARUMANAGARA REKTOR

Prof. Dr. Ir. AGUSTINUS PURNA IRAWAN

Print Security : 3582c278baa6998f877fc983a485daf9

Jl. Letjen S. Parman No. 1, Jakarta Barat 11440
P: 021 - 5695 8744 (Humas)
E: humas@untar.ac.id

Untar Jakarta
untar.ac.id

Review-Form

General Information about This Paper:
Paper ID: MS2009
Paper Title: Optimizing Elasto-Plastic Analysis of Concrete Beams Exposed to Fire: Incorporating the Influence of Concrete Cover
Review Period: Three Weeks

Paper Quality: Mark your evaluation in the suitable column. 5 indicates the best and 1 implies the worst.

ASPECT	BEST	5	4	3	2	1	WORST
Scope	Relevant			*			Irrelevant
Organization:	Excellent			*			Poor
Clarity:	High				*		Low
Length:	Too Short			*			Too Long
References:	Adequate			*			Incomplete
Correctness:	Correct			*			Incorrect
Significance:	High			*			Low
Originality:	High		*				Low
Attachments:	Helpful			*			Unnecessary
If Survey Coverage:	Broad				*		Shallow
Contribution:	Significant			*			No new
Expression	Clearly					*	Vague
Grammar	Good	*					Poor

Please make very detailed technical and editorial comments and suggestions directly on the manuscript. Your comments are an invaluable aid to the author(s) to help in improving the overall technical quality, utility, and readability of the material. Particular attention should be given to details that guide possible revisions, or that clearly explain reasons for rejection. Please summarize comments that appear on the manuscript to help the author(s) focus on the major issues you have raised in your review.

What are the contributions of this paper?

Recommendation ( )

A) Accept

B) Revise and Accept (Minor Revision)

C) Major Revision and Resubmit

D) Reject

Comments
Confidential Comments to the Editor-in-Chief Need more explanation about the modelling in ABAQUS especially the modelling of the bonding between concrete and longitudinal Need more numerical about the room temperature Need more theory of the concrete damage plasticity model **Need more explanation for table 6. (the increasing load is not linear like table 4 and 5)**
Comments to the Author(s) A) If you agree to accept this paper, please illustrate your reasons why this paper is qualified to be published in the journal in detail, or provide revision suggestions if you have any. ● Why this paper is qualified: This paper have an experiment that have been modeled in Finite Element Analysis. If the author can add the modelling in ABAQUS, this is good for other author or researcher ● Revision suggestions: Specific comments and suggestions (on layout and format, title, abstract, introduction, method, statistical errors, results, conclusion/discussion, language and references) will be greatly appreciated. **If the paper needs professional English editing, kindly give some examples for reference.** B) If you think this paper needs major modification and resubmission, please provide summary and detail revision suggestions (on layout and format, title, abstract, introduction, method, statistical errors, results, conclusion/discussion, language and references.). Please point out the section(s) where you think an error/flaw occurs. **If the paper needs professional English editing, kindly give some examples for reference as well.** ● Detail revision suggestions: C) If you think this paper should be rejected, please expound the reasons why it is not of sufficient quality/novelty or seriously flawed to be published in the journal.

Would you be willing to review a revision of this manuscript? Yes (ok) No ( )

Thank you very much for your contribution!

Optimizing Elasto-Plastic Analysis of Concrete Beams Exposed to Fire: Incorporating the Influence of Concrete Cover

János Szép[a], Sarah Khaleel Ibrahim[a*], Muayad Habashneh[a] and Majid Movahedi Rad[a]
[a] *Department of Structural and Geotechnical Engineering, Széchenyi István University, H-9026 Győr*

Abstract. This study utilizes a recently validated finite element model to conduct advanced analysis on the optimized performance of reinforced concrete beams under elevated temperatures, with a precise focus on the influence of concrete cover. The main aim is to enhance the utilization of concrete beams in high-temperature environments by providing valuable insights into their behaviour when subjected to thermal loading. Through extensive exploration of various concrete cover thicknesses, a specialized code is developed to optimize elastic-plastic analysis, presenting a systematic approach to address residual plastic deformations in steel bars within concrete elements. The research employs numerical modelling techniques using ABAQUS software, validated against experimental data from laboratory tests on benchmark studies. Concrete damage plasticity (CDP) constitutive models accurately represent concrete behaviour in the numerical simulations. The optimization process entails establishing objective functions to optimize applied plastic loads for each concrete cover scenario, with constraints applied to the complementary strain energy of residual internal forces within steel bars. This methodology effectively manages plastic deformations and elucidates the transition of beams starting in elastic case into elasto-plastic conditions and eventually to plastic states, based on varying complementary strain energy values.

Keywords. Complementary strain energy, Optimal analysis, reinforced concrete beam, elevated temperature, limited residual plastic deformations, finite element, heat distribution.

1. Introduction

This study builds on prior research by Szep et al. [1], which explored the influence of elevated temperatures considering reinforced concrete beams' load-bearing capacity. The aim is to address a critical gap in fire-resistant concrete design by examining different concrete cover values to prevent structural failure. Other relevant studies by Kigha et al. [2], Unluoglu et al. [3], and Kodur and Agrawal [4] have also explored fire effects on reinforced concrete structures, including post-fire structural integrity and behaviour of structural reinforcement steel. Additionally, Complementary strain energy, which offers insights into internal forces and stresses within structures, has been a focal point for several researchers [5-11]. For instance, Rad et al. [12] developed a computational model

[1] Corresponding Author: Sarah Khaleel Ibrahim , Email: sarah.khaleel.ibrahim@hallgato.sze.hu

to manage the plastic behaviour of reinforced concrete beams based on complementary strain energy.

This study extends previous research by analysing the temperature effect on different concrete cover scenarios. It employs complementary strain energy as a boundary for plastic behaviour in reinforced concrete beams under elevated temperature. Through numerical model calibration and novel code implementation, researchers control plastic behaviour based on a constant rate of complementary strain energy (W_{p0}). The number of yielding parts within steel bars, influenced by steel volume and allowable W_{p0} values, governs the complementary strain energy (W_p), that is affected by variations in concrete cover. The investigation explores how uncertainties in these variables impact beam behaviour under elevated temperatures, reflecting real-world construction errors.

Subsequent sections of the paper detail the approaches used in this study (Section 2), describe the modelled beams (Section 3), discuss the obtained results (Section 4), and present the most significant conclusions (Section 5).

2. Principles and methods

2.1. Complementary strain energy work

This widely-used method in plastic analysis and design integrates residual stresses through complementary strain energy, a well-established concept across different structures [5, 6]. A suitable computational technique has been developed to comprehensively assess plastic behaviour and control residual deformations, particularly useful when constraints on strain energy quantity are needed. Now, we outline the residual forces that contribute to this supplementary strain energy:

$$W_p = \frac{1}{2\mathrm{E}} \sum_{\mathrm{i}=1}^{\mathrm{n}} \frac{l_i}{A_i} N_i^{R^2} \leq W_{p0}. \tag{1}$$

W_{p0} represents the maximum elastic strain energy for a structure, setting a threshold for the plastic deformations in the rebar. Equation (1) defines this threshold, with E denoting the Young's modulus, N_i^R representing residual forces, l_i standing for bar length, and A_i indicating cross-sectional area. N^{pl} and N^{el} depict internal plastic and elastic forces, respectively.

$$N^R = N^{pl} - N^{el}. \tag{2}$$

Providing that:

$$N^{el} = F^{-1} G^T K^{-1} P_0. \tag{3}$$

Matrix F symbolizes adaptability, whereas Matrix G embodies geometry; however, Matrix K delineates rigidity

2.2. Optimal work

This part presents a mathematical procedure for optimizing the loading of reinforced concrete beams under elevated temperatures. The non-linear optimization technique is introduced to maximize the applied load (F^{pl}) while controlling plastic deformation (W_{p0}).

$$Max. \rightarrow F^{pl} \tag{4}$$

$$Subjected\ to{:}\ N^{el} = F^{-1}GK^{-1}P_0 \tag{5}$$

$$-\overline{N^{pl}} \leq N^{Pl} \leq \overline{N^{pl}} \tag{6}$$

$$\frac{1}{2\mathrm{E}} \sum_{\mathrm{i}=1}^{\mathrm{n}} \frac{l_i}{A_i} N_i^{R^2} \leq W_{p0}. \tag{7}$$

Equation (5) computes elastic forces in steel, while Equation (6) sets plastic limitations with N^{pl} as the ultimate load. Equation (7) constrains complementary strain energy. Integrated with ABAQUS, this process determines optimal loads for each model.

3. Models Properties

In line with [1], RC beam models were simulated using ABAQUS [13] software for FE analysis. Figure 1 outlines beam geometry, boundaries, and loading conditions for validation. The beams, 1800 mm long by a cross section of 120 mm × 200 mm, which studied for various concrete cover (CC) thicknesses' effects under fire. Three beams (CC= 20mm, CC= 30mm, and CC= 40mm) were assessed, with fire heat applied to three surfaces, excluding the top.

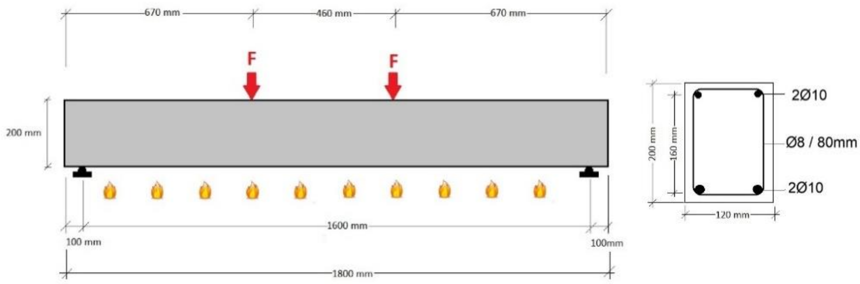


Figure 1. Considered beam with its geometry, cross-section and loading conditions.

Finite element models underwent temperature transmission analysis, shadowed by stress analysis related to temperature distribution. The study utilized the concrete damaged plasticity model (CDPM) from ABAQUS/Standard to simulate concrete responses to temperature variations, with assumed data detailed in Table 1. Key parameters were derived from Eurocode 1992-1-2 [14]. Figure 2 illustrates the temperature-induced decrease in compressive strength.

Steel reinforcing bars' temperature-dependent behaviour is captured using thermal equations from Eurocode 1992-1-2 [14]. Despite the equation's nonlinearity, the thermal expansion coefficient exhibits minimal variation with temperature. Figure 3 illustrates stress-strain curves obtained from this method. Material properties of steel reinforcing bars at ambient temperature are detailed in Table 2. Concrete properties at room temperature include a compressive strength about 25 MPa and a modulus of elacticity (E) of 23.5 GPa. An intriguing trend emerged from the analysis: increasing the thickness of the concrete cover led to a reduction in the maximum temperature within the cross-section. This indicates that a thicker concrete cover offers improved insulation and shields the internal steel reinforcement from the elevated temperatures caused by the fire. Table 3 shows the ultimate load result for the three cover cases where the outcomes displayed that the load capacity of the beams increases as the concrete cover thickness increases. This indicates that a greater concrete cover contributes to higher structural strength and resistance to deformation.

Table 1. CDP parameters.

Dilation angle	K	μ	Eccentricity	fb0/fc0
30	0.667	0.005	0.1	1.16

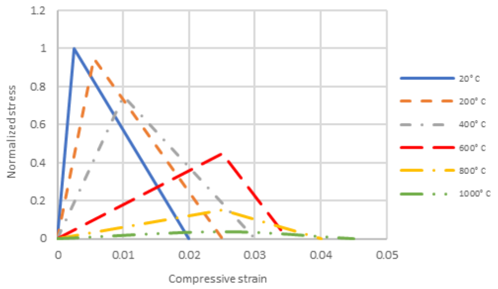


Figure 2. Concrete stress-strain ratios at different temperatures.

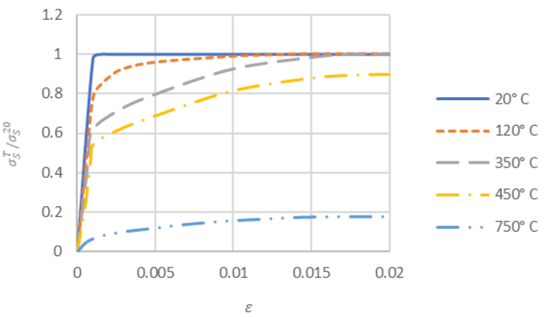


Figure 3. Stress-strain ratios of reinforcing steel at different temperatures.

Table 2. Considered steel rebars in the case of ambient temperature.

Reinforcement	ϕ (mm)	fy (MPa)	E (MPa)
Top reinforcement	10	235	200000
Bottom reinforcement	10	358	200000
Stirrups	8	235	200000

Table 3. Ultimate load results of the three cover cases.

CC (mm)	$F_{ultimate}$ – (kN)
20	20
30	22.6
40	29.3

4. Complementary Work Results and Discussion

In this part, the optimization process is used on three beam models with concrete cover values of 20 mm, 30 mm, and 40 mm. Elevated temperature loadings affected the properties of steel bars and concrete, with varying impacts depending on their proximity to heat sources and concrete cover thicknesses. Thicker concrete cover enhances beam ultimate loads by providing better protection for steel bars, especially in the bottom area where failure is mainly governed by flexural strength. The optimization process controls plastic behaviour in these beams, with complementary strain energy primarily increasing with load. Results show that complementary strain energy values inversely correlate with concrete cover thickness, serving as damage indicators, see Figure 4. Different W_{p0} values were chosen to understand their effect on beam behaviour and load values across cover cases (see Table 4, 5 and 6). Minimal W_{p0} values correspond to minimal damage in concrete and steel. For models with concrete cover values of 20 mm, 30 mm, and 40 mm, only the longitudinal bottom steel bars underwent yielding, emphasizing the importance of concrete cover thickness in structural performance.

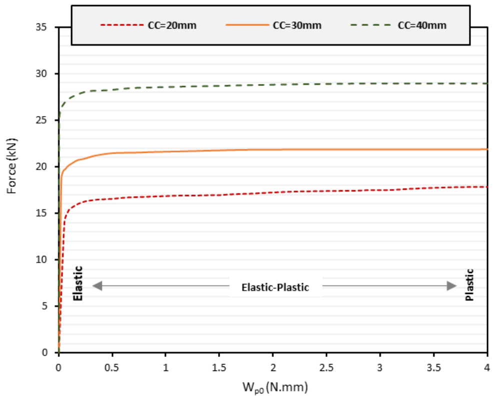


Figure 4. Load-W_{p0} relationship of the three models with different cover values.

Table 4. Damage representation for 20mm concrete cover case.

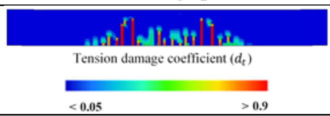
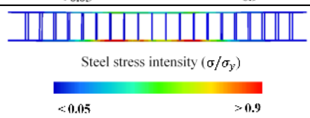
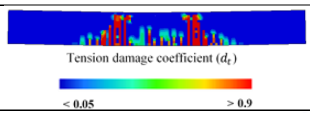
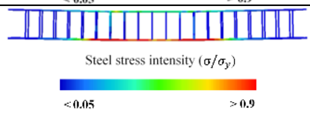
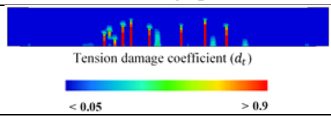
W_{p0} (N.mm)	Load (kN)	Material	Damage pattern
0.05	14	Concrete	
		Steel	
3.9	17.7	Concrete	
		Steel	

Table 5. Damage representation for 30mm concrete cover case.

W_{p0} (N.mm)	Load (kN)	Material	Damage pattern
0.023	18.8	Concrete	

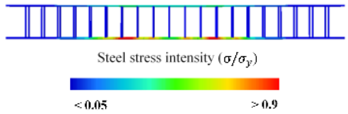
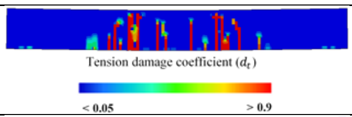
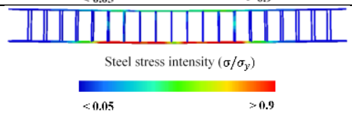
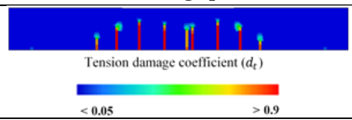
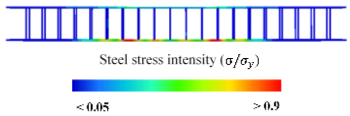
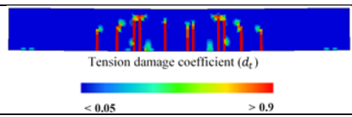
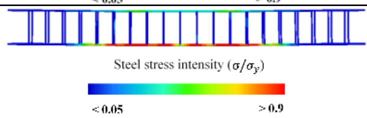
		Steel	
3.9	21.8	Concrete	
		Steel	

Table 6. Damage representation for 40mm concrete cover case.

W_{p0} (N.mm)	Load (kN)	Material	Damage pattern
0.0015	24.84	Concrete	
		Steel	
3.9	21.8	Concrete	
		Steel	

5. Conclusions

In conclusion, this study sheds light on the performance of reinforced concrete beams under elevated temperature loading, taking into account varying concrete cover values. Key findings include:

- Impact of Elevated Temperature Loading: Heat application from three sides affected steel bars and concrete properties, with upper concrete parts experiencing less heat impact. Steel bars near the heat source showed decreased yield strength.
- Effect of Concrete Cover Thickness: Thicker cover enhanced beam ultimate loads, providing better protection for steel bars, especially in areas governed by flexural strength.
- Control of Plastic Behaviour: The optimization process effectively managed beam plastic behaviour using complementary strain energy values. Higher W_{p0} values correlated with increased load and damage intensity, particularly in thinner concrete cover areas.

- Role of Complementary Strain Energy: W_{p0} values served as damage indicators, with less concrete cover resulting in higher initial stress values and greater damage. Conversely, thicker cover led to stronger beams with reduced damage.

Overall, these insights underscore the importance of concrete cover thickness and complementary strain energy in optimising structural behaviour and fire resistance of reinforced concrete beams, contributing to enhanced design and safety protocols in fire-exposed structures.

References

[1] Szep, J., Habashneh, M., Rad, M.M., The role of concrete cover on the load bearing capacity of reinforced concrete beams in fire: a finite element analysis, in P. Ivanyi, J. Kruis, B.H.V. Topping, (Editors), "Proceedings of the Seventeenth International Conference on Civil, Structural and Environmental Engineering Computing", Civil-Comp Press, Edinburgh, UK, Online volume: CCC 6, Paper 11.9, 2023, doi:10.4203/ccc.6.11.9.

[2] Kigha, F., Sadeeq, J.A. and Abejide, O.S., 2015. Effects of temperature levels and concrete cover thickness on residual strength characteristics of fire exposed reinforced concrete beams. Nigerian Journal of Technology, 34(3), pp.429-437. https://doi.org/10.4314/njt.v34i3.1.

[3] Ünlüoğlu, E., Topçu, İ.B. and Yalaman, B., 2007. Concrete cover effect on reinforced concrete bars exposed to high temperatures. Construction and Building Materials, 21(6), pp.1155-1160. https://doi.org/10.1016/j.conbuildmat.2006.11.019.

[4] Kodur, V.K.R. and Agrawal, A., 2017. Effect of temperature induced bond degradation on fire response of reinforced concrete beams. Engineering Structures, 142, pp.98-109. https://doi.org/10.1016/j.engstruct.2017.03.022.

[5] Kaliszky, S. and Lógó, J., 1997. Optimal plastic limit and shake-down design of bar structures with constraints on plastic deformation. Engineering Structures, 19(1), pp.19-27. https://doi.org/10.1016/S0141-0296(96)00066-1.

[6] Kaliszky, S. and Lógó, J., 1998. Discrete optimal design of elasto-plastic trusses using compliance and stability constraints. Structural optimization, 15, pp.261-268. https://doi.org/10.1007/BF01203541.

[7] Kaliszky, S. and Logo, J., 1999. Optimal strengthening of elasto-plastic trusses with plastic deformation and stability constraints. Structural optimization, 18(4), pp.296-299. https://doi.org/10.1007/BF01223313

[8] Kaliszky, S. and Lógó, J., 2002. Plastic behaviour and stability constraints in the shakedown analysis and optimal design of trusses. Structural and Multidisciplinary Optimization, 24, pp.118-124. https://doi.org/10.1007/s00158-002-0222-2.

[9] Rad, M.M. and Ibrahim, S.K., 2021. Optimal plastic analysis and design of pile foundations under reliable conditions. Periodica Polytechnica Civil Engineering, 65(3), pp.761-767. https://doi.org/10.3311/PPci.17402.

[10] Khaleel Ibrahim, S. and Movahedi Rad, M., 2023. Limited optimal plastic behavior of RC beams strengthened by carbon fiber polymers using reliability-based design. Polymers, 15(3), p.569. DOI: 10.3390/polym15030569.

[11] Khaleel Ibrahim, S. and Movahedi Rad, M., 2023. Reliability-based probabilistic numerical plastically limited analysis of reinforced concrete haunched beams. Scientific Reports, 13(1), p.2670. DOI: 10.1038/s41598-023-29930-0

[12] Rad, M.M., Ibrahim, S.K. and Lógó, J., 2022, May. Limit design of reinforced concrete haunched beams by the control of the residual plastic deformation. In Structures (Vol. 39, pp. 987-996). Elsevier. https://doi.org/10.1016/j.istruc.2022.03.080.

[13] Simulia, D.S., 2018. ABAQUS 2018 User's manual. Dassault Systems, Analysis user's guide, Volume IV: Elements.

[14] For Standardization EC. Eurocode 2: Design of concrete structures-part 1.2 General rules-structural fire design 2004.