


CURRICULUM VITAE

Name	Richard Shaun Walls	
Nationality	South African	
Current Occupation	Associate Professor – Stellenbosch University	
E-mail address	rwalls@sun.ac.za	
Languages	English (Excellent), Afrikaans (Conversational). Basic Biblical Greek.	
Religion	Christian	
YouTube Channel	https://www.youtube.com/channel/UCUZH8qYZwKToJa6n2T9FhyA	
FireSUN Channel	https://www.youtube.com/channel/UCv1bBnE4i6eiuYFBEDO3K1Q?view_as=subscriber	

QUALIFICATIONS

PhD (Civil Engineering)	Stellenbosch University. 2013-2016.
MSc (Structural) (with distinction):	University of the Witwatersrand. 2009-2010.
G.D.E. (with distinction):	University of the Witwatersrand. 2009-2010.
BSc.Eng (Civil) (with distinction):	University of the Witwatersrand. 2005-2008
Pr. Eng.:	Registered as a professional engineer with ECSA. 2014.
BTh (with distinction):	SA Theological Seminary – Part-time studies. 2006-2013.

RESEARCH, PUBLICATIONS & UNIVERSITY

Research Interests and Experience

Richard is the head of the Fire Engineering Research Unit at Stellenbosch University, Africa's first research team with a focus on fire engineering and structural fire design. Various fire related topics are currently being investigated, such as the design of steel structures in fire, analysis of structures in fire, forensic fire investigations, 3D printed concrete in fire, materials behaviour and informal settlement fire behaviour. Full-scale fire tests on shacks have been conducted in conjunction with the Western Cape Local Government Disaster Management, Fire & Rescue Services and the Breede Valley Fire Training Centre. The behaviour of different smoke and fire alarms in informal settlements has been carried out. Consulting work has been done for companies developing rational structural fire design systems, and ascertaining the fire resistance of products. He served as a reviewer of the fire design annex of the soon to be released SANS 10162-1 steel design code, and has reviewed papers for various local and international journals. He was part of the team analysing the Knysna fire disaster, sponsored by Santam, and specifically considered why almost 1000 homes were lost in South Africa's largest wildland fire disaster. In 2017 he was awarded the emerging researcher of the year in the engineering faculty at Stellenbosch University. His research has been covered by multiple newspapers, radio stations and websites. Previous research has focussed on structural optimisation, demolition engineering and steelwork design.

PhD Thesis – “A beam finite element for the analysis of structures in fire”

An analysis methodology and beam finite element has been developed which allows for the simplified design of structures in fire. This thesis was completed under the supervision of Dr Hennie de Clercq and Dr Celeste Viljoen. Refer to the end of this document for the abstract of this thesis, or to <http://scholar.sun.ac.za/handle/10019.1/100331>.

Journal Papers (paper submitted but under review in italics):

- [1] Elvin A, Walls R, Cromberge D. Optimising structures using the principle of virtual work. *J South African Inst Civ Eng* 2009;51.
- [2] Walls R, Elvin A. An algorithm for grouping members in a structure. *Eng Struct* 2010;32:1760–8. doi:10.1016/j.engstruct.2010.02.027.
- [3] Walls R, Elvin A. Automated structural design and optimisation. *Struct Eng* 2010;88:30–4.
- [4] Walls R, Elvin A. Mass and stiffness distributions in optimized ungrouped unbraced frames. *Int J Steel Struct* 2010;10. doi:10.1007/BF03215833.
- [5] Walls R, Elvin A. Optimizing Structures Subject to Multiple Deflection Constraints and Load Cases Using the Principle of Virtual Work. *J Struct Eng* 2010;136:1444–52. doi:10.1061/(ASCE)ST.1943-541X.0000246.
- [6] Walls RS, Viljoen C. A comparison of technical and practical aspects of Eurocode 3-1-1 and SANS 10162-1 hot-rolled steelwork design codes. *Civ Engr S Afr* 2016;58:16–25. doi:10.17159/2309-8775/2016/v58n1a2.
- [7] Walls RS, Viljoen C, de Clercq H, Clifton GC. Reliability Analysis of the Slab Panel Method (SPM) for the Design of Composite Steel Floors in Severe Fires. *J Struct Fire Eng* 2017;8:84–103. doi:10.1108/JSFE-01-2017-0008.
- [8] Walls R, Olivier G, Eksteen R. Informal settlement fires in South Africa: Fire engineering overview and full-scale tests on “shacks.” *Fire Saf J* 2017;91:997–1006. doi:10.1016/j.firesaf.2017.03.061.
- [9] van Jaarsveldt WJ, Walls RS, van der Klashorst E. Experimental Testing and Finite Element Modelling of Steel Columns Weakened to Facilitate Building Demolition. *Int J Steel Struct* 2018;18:1483–96. doi:10.1007/s13296-018-0049-3.
- [10] Walls RS, Viljoen C, de Clercq H. Analysis of Structures in Fire as Simplified Skeletal Frames Using a Customised Beam Finite Element. *Fire Technol* 2018;54:1655–82. doi:10.1007/s10694-018-0762-7.
- [11] Cicione A, Walls RS, Kahanji C. Experimental Study of Fire Spread Between Multiple Full Scale Informal Settlement Dwellings. *Fire Saf J* 2019;105:19–27. doi:10.1016/j.firesaf.2019.02.001.
- [12] Marx H, Walls R. Thermal behaviour of a novel non-composite cellular beam floor system in fire. *J Struct Fire Eng* 2019;10:354–72. doi:10.1108/JSFE-10-2018-0032.
- [13] Kloos M, Walls RS. Finite Element Modelling of the Structural Behaviour of a Novel Cellular Beam Non-composite Steel Structure in Fire. *Int J Steel Struct* 2019. doi:10.1007/s13296-019-00215-5.
- [14] Walls RS, Eksteen R, Kahanji C, Cicione A. Appraisal of fire safety interventions and strategies for informal settlements in South Africa. *Disaster Manag Prev* 2019;28:343–58. doi:10.1108/DPM-10-2018-0350.
- [15] Walls R, Viljoen C, de Clercq H. A nonlinear, beam finite element with variable, eccentric neutral axis. *Eng Struct* 2019;187:341–51. doi:10.1016/j.engstruct.2019.02.056.
- [16] Kahanji C, Walls RS, Cicione A. Fire spread analysis for the 2017 Imizamo Yethu informal settlement conflagration in South Africa. *Int J Disaster Risk Reduct* 2019. doi:10.1016/j.ijdrr.2019.101146.
- [17] Walls R, Viljoen C, de Clercq H. Parametric investigation into the cross-sectional stress-strain behaviour, stiffness and thermal forces of steel, concrete and composite beams exposed to fire. *J Struct Fire Eng* 2019;ahead-of-p. doi:10.1108/JSFE-10-2018-0031.
- [18] Cicione A, Beshir M, Walls RS, Rush D. Full-Scale Informal Settlement Dwelling Fire Experiments and Development of Numerical Models. Springer US; 2019. doi:10.1007/s10694-019-00894-w.
- [19] Wang Y, Bertrand C, Beshir M, Kahanji C, Walls R, Rush D. Developing an experimental database of burning characteristics of combustible informal dwelling materials based on South African informal settlement investigation. *Fire Saf J* 2020;111:102938. doi:10.1016/j.firesaf.2019.102938.
- [20] de Koker N, Walls RS, Cicione A, Sander ZR, Löffel S, Claasen JJ, et al. 20 Dwelling Large-Scale Experiment of Fire Spread in Informal Settlements. *Fire Technol* 2020. doi:10.1007/s10694-019-00945-2.
- [21] Löffel S, Walls R. Development of a full-scale testing methodology for benchmarking fire suppression systems for use in informal settlement dwellings. *Int J Disaster Risk Reduct* 2020;45:101451. doi:10.1016/j.ijdrr.2019.101451.
- [22] *Löffel S, Walls R. Determination of water application rates required for communities to suppress post-flashover informal settlement fires based on numerical modelling and experimental tests. Fire Mater* 2019;Under revi.
- [23] *van der Westhuyzen S, Walls R, de Koker N. Fire tests of South African cross-laminated timber wall panels: fire ratings, charring rates, and delamination. Civ Eng* 2019;Under revi.
- [24] *Volkman J, Walls R, de Koker N. Implementation of the Fire Beam Element method into OpenSees for the analysis of structures in fire. Adv Struct Eng* 2019;Under revi.
- [25] *Cicione A, Kruger J, Walls R, van Zijl G. An experimental study of the behavior of 3D printed concrete at elevated*

temperatures. *Fire Saf J* 2020;Under revi.

- [26] Flores Quiroz N, Walls R, Cicione A. *Developing a Framework for Fire Investigations in Informal Settlements. Fire Saf J* 2020;Under revi.
- [27] Cicione A, Wade C, Spearpoint M, Gibson L, Walls R, Rush D. *A preliminary investigation to develop a semi-probabilistic model of informal settlement fire spread using B-RISK. Fire Saf J* 2020;Under revi.

Conference Papers:

- [1] Walls RS, Elvin AA. A search algorithm for optimizing the grouping of members. *Adv. Trends Struct. Eng. Mech. Comput. - Proc. 4th Int. Conf. Struct. Eng. Mech. Comput. SEMC 2010*, 2010.
- [2] Walls RS, Elvin AA. The virtual work optimization method applied to structures: An investigation into cellular beams versus trusses. *Adv. Trends Struct. Eng. Mech. Comput. - Proc. 4th Int. Conf. Struct. Eng. Mech. Comput. SEMC 2010*, 2010.
- [3] Walls RS, Ekolu SE. An investigation into failures and problems of industrial floors on the ground - With an emphasis on case studies. *Concr. Repair, Rehabil. Retrofit. III - Proc. 3rd Int. Conf. Concr. Repair, Rehabil. Retrofit. ICCRRR 2012*, 2012.
- [4] Walls RS, Viljoen C, de Clercq H, Retief J. A critical review on current and proposed structural fire engineering codes for steelwork in South Africa. In: S.O. Ekolu et al, editor. *Constr. Mater. Struct.*, Johannesburg: IOS Press; 2014, p. 1134–40.
- [5] Walls RS, Botha M. Towards a Structural Fire Loading Code for Buildings in South Africa. In: Zingoni A, editor. *Insights Innov. Struct. Eng. Mech. Comput.*, Cape Town: Taylor & Francis; 2016, p. 1761–5.
- [6] Walls RS. Teaching structural analysis and design: Evaluation and student feedback on various techniques and interventions. In: Zingoni A, editor. *Insights Innov. Struct. Eng. Mech. Comput.*, Cape Town: Taylor & Francis; 2016, p. 2169–74.
- [7] Van Jaarsveldt WJ, Walls RS. Predicting the failure load of steel columns weakened to facilitate demolition of a structure. *Insights Innov. Struct. Eng. Mech. Comput. - Proc. 6th Int. Conf. Struct. Eng. Mech. Comput. SEMC 2016*, 2016.
- [8] Walls RS. Demolition of steel structures: structural engineering solutions for a more sustainable construction industry. In: Bahei-El-Din Y, Hassan M, editors. *Adv. Technol. Sustain. Syst.*, Cairo: Springer; 2017, p. 3–8. doi:10.1007/978-3-319-48725-0_1.
- [9] Walls RS, Zweig P. Towards sustainable slums: understanding fire engineering in informal settlements. In: Bahei-El-Din Y, Hassan M, editors. *Adv. Technol. Sustain. Syst.*, Cairo: Springer; 2017, p. 93–8. doi:10.1007/978-3-319-48725-0.
- [10] Gibson LL, Rush D, Wheeler O, Cairns R, Walls R. Fire detection in informal settlements. In: Chrysoulakis N, Erbertseder T, Zhang Y, editors. *Remote Sens. Technol. Appl. Urban Environ. III*, Berlin: SPIE; 2018, p. 31. doi:10.1117/12.2501885.
- [11] Walls R, Kahanji C, Cicione A, Jansen van Vuuren M. Fire dynamics in informal settlement “shacks”: Lessons learnt and appraisal of fire behavior based on full-scale testing. *11th Asia-Oceania Symp. Fire Sci. Technol. Symp.*, Taiwan: 2019.
- [12] Walls RS, Cicione A, Messerschmidt B, Almand K. *Africa: The next frontier for fire safety engineering? Interflam Proc.*, London: 2019.
- [13] Cicione A, Walls RS. Towards a Simplified Fire Dynamic Simulator Model to Analyse Fire Spread Between Multiple Informal Settlement Dwellings Based on Full-Scale Experiments. *Interflam Proc.*, 2019.
- [14] Cicione A, Walls R. Estimating time to structural collapse of informal settlement dwellings based on structural fire engineering principles. In: Zingoni A, editor. *Adv. Eng. Mater. Struct. Syst. Innov. Mech. Appl.*, CRC Press; 2019, p. 1909–14. doi:10.1201/9780429426506.
- [15] Dunn T, Walls R. Demolition engineering: Determination of the axial load capacity of steel columns weakened by horizontal and diagonal cuts. In: Zingoni A, editor. *Adv. Eng. Mater. Struct. Syst. Innov. Mech. Appl.*, CRC Press; 2019, p. 2209–14. doi:10.1201/9780429426506.
- [16] Mitchell D, Walls R. Demolition engineering: Lateral load carrying capacity of weakened steel beams. In: Zingoni A, editor. *Adv. Eng. Mater. Struct. Syst. Innov. Mech. Appl.*, CRC Press; 2019, p. 2215–20. doi:10.1201/9780429426506.

Reports, articles and technical documents:

- [1] Walls R, Elvin A. Automating Structural Design: Getting Computers to Design. *Steel Constr* 2009;33:32–4.
- [2] Walls R. Consol Nigel: A state-of-the-art glass factory takes shape. *Civ Eng* 11AD;July:51–3.
- [3] Geldenhuys C, Walls R. Saving Money on Passive Fire Protection - Designing Composite Floors in Fire: the Slab Panel Method. *Steel Constr* 2015;39:30–2.
- [4] de Clercq H, Walls R. Student to engineer - easing the transition by way of the final-year design project. *Civ Eng*

2015:43–8.

- [5] Zweig P, Pharoah R, Eksteen R, Walls RS. Installation of Smoke Alarms in an Informal Settlement Community in Cape Town, South Africa – Final Report. 2018.
- [6] Walls R, Moran A, van Straten A, Sander Z. Knysna Fires Project – Analysis and lessons learnt from the homes and structures which were damaged or destroyed in the incident. Cape Town: Santam; 2019. doi:10.13140/RG.2.2.18118.11843.
- [7] Forsyth G, Le Maitre DC, Van Den Dool R, Walls R, Pharoah R, Fortune G. The Knysna Fires of 2017: Learning from the disaster. 2019.
- [8] McGlade J, Pulwarty R, Abrahams J, Bankoff G, Cooper-Knock S, Cotecchia F, et al. GAR: Global Assessment Report on Disaster Risk Reduction 2019. Geneva, Switzerland: United Nations Office for Disaster Risk Reduction; 2019. doi:http://doi.org/10.13140/RG.2.2.23985.22889.

Examples of radio and television interviews conducted

- [1] AlgoaFM. The risk of mega-fires... 2019.
- [2] CapeTalk. Stellies to offer postgrad degree in fire safety and engineering 2018. <http://www.capetalk.co.za/articles/318173/stellies-to-offer-postgrad-degree-in-fire-safety-and-engineering> (accessed August 6, 2018).
- [3] CapeTalk. Fighting fire with education 2018. <http://www.capetalk.co.za/podcasts/140/the-kieno-kammies-show/106818/fighting-fire-with-education> (accessed September 6, 2018).
- [4] GoodHopefm. Santam Knysna Fires Radio Interview n.d.
- [5] Kfm. Stellies to offer postgrad degree in fire safety and engineering n.d. <http://kfm.co.za/articles/2018/09/06/stellies-to-offer-postgrad-degree-in-fire-safety-and-engineering> (accessed September 6, 2019).
- [6] Radio2000. Santam Knysna Fires Radio Interview n.d.
- [7] SAfm. An in-depth authoritative and independent report, commissioned by short-term insurer Santam ,into the devastating fires 2019. <https://iono.fm/e/697277> (accessed June 7, 2019).
- [8] SAfm. Informal settlement fires in December 2019.

Researcher & Student Supervision:

Postdoc: Dr Charles Kahanji 2017-2018

Dr Nico de Koker – 2018-2019

Dr Antonio Cicione – 2020-

PhD: Cicione, A – “Fire dynamics in informal settlements” – 2017-2019

Ngwenya, D – “Investigating water application rates for sprinkler roof cooling on atmospheric petrochemical fixed-roof storage tanks during a fire” – 2018-

Zimba, N – “Design of industrial buildings in fire” – 2017-

Narayanan, V – “Test methods for evaluating construction materials in informal settlements” – 2019-

Flores Quiroz, N – “Forensic investigations in informal settlements” – 2019-

Claassen, J – “Full-scale testing of the SAISC cellular beam structure” – 2018-

MEng: Van Jaarsveldt, WJ – “Predicting the failure load of columns weakened to facilitate demolition of steel structures” – 2015-2016. Co-supervisor.

Kloos, M – “Structural behaviour of a new cellular steel beam structural system in fire” – 2016-2017

Marx, H – “Thermal behaviour of a new cellular steel beam structural system in fire” – 2016-2017

Volkman, J – “Modelling of structures in fire using beam elements” – 2017-2018

Loffel, S – “Suppression of fires in informal settlements” – 2018-2019

Myburgh,

Fourie, S – “Behaviour of the Voidcon flooring system in fire” – 2018-2019
 Gous, M – “Behaviour of South African passenger trains in fire”- 2019-
 Sander, Z – “Behaviour of recycled bottle EcoBricks structures in fire”- 2019-
 Strauss, L – “Analysis of 3D structural frames in fire using the fire beam element (FBE)”- 2019-
 Sulon, D – “Behaviour of timber connections in fire” – 2019-
 Botha, A – “Behaviour of recycled construction materials in fire” – 2020- . Co-supervisor.
 Oosthuysen, C – “Behaviour of shipping containers in fire”. 2020- . Co-supervisor.
 Van Rensburg, K – “Large building structural modelling in fire”. 2020- .
 Whitehead, M – “Understanding and developing requirements for fire testing of materials in South Africa”. 2020.

Approximately 4-5 final year (honours) research projects are also supervised each year. The table below summarises details.

	Current	Graduated	Total
Masters	8	6	14
PhD	5	1	6

Lecturing

- GO446 – Under-graduate course: Advanced Design Project
- SD424 – Design of structural steelwork
- Post-graduate course: Advanced Concrete Design
- Post-graduate course: Structural Fire Engineering
- Post-graduate course: Fire behaviour
- Advanced design of steel structures in fire – series of lectures – April 2014
- Various lectures on advanced geotechnical engineering, steel design and construction management.
- Refer to the YouTube channels listed above for various video lectures produced.

Research Grants and Funding Received From:

1. NRF-DAAD
2. NRF Thuthuka Grant
3. The Ove Arup Foundation
4. Global Challenges Research Fund from the UK in conjunction with the University of Edinburgh.
5. SU Institute of Structural Engineering – Start-up funding
6. Various Stellenbosch University travel and research grants.
7. SA Institute of Steel Construction
8. Lloyd’s Register Foundation – “Fire Engineering Education For Africa”
9. THRIP funding under the Department of Trade and Industry
10. Western Cape Government Department of Human Settlements
11. Voidcon Research and Development project under the Department of Trade & Industry

Total funding generated: ±R11 million

University accolades

Stellenbosch University Awards: Best post-graduate thesis in Civil Engineering 2016. Best runner-up paper and presentation at the Scholarship of Teaching & Learning Conference 2015. Emerging Researcher of the Year in the SU Faculty of Engineering 2017.

Wits University Awards: Cement and Concrete Institute Prize, Jere Jennings Prize for Civil Engineering, Jere Jennings Prize in Geotechnical Engineering, Desmond Midgeley Knight-Piesold Prize for Hydrology, Murray and Roberts Prize in Civil Engineering, R Kirkpatrick and Son Award, JSD Structural Engineering Prize, Dean's List, Best Academic Student in the class every year of BSc studies, best research presentation in engineering at the Wits Post-graduate Research Symposium.

CONSULTING EXPERIENCE

Employer: BSM Baker – Civil and structural engineers

Director and mentor: Geoff Baker (Pr. Eng.)

Period employed: January 2010 – December 2013: Full-time employment.
January 2014 – December 2015: Part-time consulting.

Position held: Structural engineer

During employment at BSM Baker extensive experience has been gained in the design, management, supervision and financial control of industrial, petrochemical and commercial structures. Key areas involved with include: steelwork design; concrete design; composite design; draughting; computer modelling of structures; foundation design; design of liquid retaining structures; design of glass bottle factories, batch houses and associated works; project management; budgeting; tendering; managing staff; financial control and invoicing on projects; site supervision; petrochemical facilities and fire-fighting design. Much time has been spent on construction sites and in existing or new buildings during projects. Recognition as a professional engineer (Pr. Eng.) was obtained in 2014, based on the experience and technical work undertaken.

Selected Consulting Projects

Important projects involved with while at BSM Baker include:

- Consol Nigel Factory – a R1.2bn greenfields glass factory. The batch plant, offloading pit, ancillary services, transfer gantries etc. were designed for this project. A great deal of time was also spent on tendering and then doing site supervision during construction.
- An R80m batch house for Nampak's new glass furnace line. All budgeting and design were personally completed.
- Numerous upgrades at the Consol Clayville, Pretoria, and Wadeville factories
- A R30m rebuild to the Consol Bellville factory
- A R2.5bn crude oil storage facility to be constructed in the Western Cape. All preliminary design, budgeting and management of the project were completed.

- Preliminary design work on a R1.8bn coal handling terminal to be constructed in Richard's Bay
- A R12.5m extension to a factory for Pford South Africa, with complicated details of tying into 3 existing structures.
- Design of a tower for wind turbines
- Design of a numerous warehouses
- Various other industrial structures including substations, chemical containment vessels, gantries, bunkers etc.



Consol Nigel site during construction



Consol Nigel Batch Plant



Consol Nigel Furnace Building & Warehouse



Consol Nigel Batch Plant on completion



Batch Plant, Johannesburg



Batch Plant, Johannesburg



Storage building, Johannesburg



Pharmaceuticals warehouse, Johannesburg



Pharmaceuticals warehouse, Johannesburg



Manufacturing facility, Johannesburg



Manufacturing facility, Johannesburg



Church - Soweto



Mining processing structures – South America

SCHOOLING AND INTERESTS

- School accolades: Head Boy, Top 50 Matric Student in South Africa for IEB, Top Academic Scholar at De La Salle, prefect, debating captain, representative on the Johannesburg Junior City Council.
- Awards: Exceptional leadership, Outstanding Loyalty, All-Round Proficiency, Top tennis player, Public speaking, Geography, Additional Mathematics and Mathematics.
- Sports in school: Cricket (1st team), tennis (1st Team), athletics, rugby, soccer and cross-country.
- Cultural in school: Debating (captain), public speaking (best speaker), chess and drama.
- Cultural outside of school: Represented South Gauteng for the Inter-provincial Maths Olympiad 2003.
Made it to the finals of the South African Harmony Gold Maths Olympiad.
- Current interests: Teaching Sunday school, running a church home group, reading, mountain biking, running, hiking, theology and the outdoors.
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SUMMARY OF EXPERIENCE, WORK & SCHOOLING

- Jan 2020 – Present Associate professor in structural and fire engineering – Stellenbosch University
- July 2017 – Dec 2019 Senior lecturer in structural engineering – Stellenbosch University
- Aug 2014 – Jun 2017 Lecturer in structural engineering – Stellenbosch University
- Jan 2014 – Dec 2016 PhD (Civil Engineering)
- Jan 2010 – Dec 2013 Structural engineer with BSM Baker

Jan 2009 – Dec 2009 Full-time work on a full research MSc and separate GDE (Graduate Diploma in Engineering). Both degrees were completed and awarded in 2010 at Wits University.

Oct 2006 – Aug 2013 BTh (Bachelor in theology). SA Theological Seminary. Part-time, correspondence studies.

Jan 2005 – Dec 2008 BSc.Eng (Civil) (with distinction).

Jan 2004 – Dec 2004 Outdoors activity instructor at Frontier Centre (UK). Travelled through Europe.

Apr 1994 – Dec 2003 De La Salle Holy Cross College Junior / Senior Schools (Johannesburg)

Jan 1991 – Apr 1994 Bergvliet Primary School (Cape Town)

PhD ABSTRACT

All building structures require a specified fire resistance rating and numerous procedures have been produced for ensuring this. In engineering practice designers can generally not perform detailed structural fire designs on buildings due to the high computational modelling requirements of most modern structures, and so they typically resort to conservative prescriptive methods instead. Hence, design engineer orientated methods are required to improve fire safety while providing more economical buildings. The goal of this dissertation is to provide a simple, but technically accurate, model for the analysis of structures in fire, including composite structures, which considers buildings as skeletal frames.

To achieve this end a beam finite element has been developed that has a moving, eccentric neutral axis that accounts for material properties that change as structures heat up. A composite bending stiffness, axial stiffness and resultant thermal forces are calculated for a generic cross-section. Material and geometric nonlinearity is considered. The properties of any number of materials (e.g. a steel beam, concrete slab and reinforcing steel) are represented by single beam properties. These calculated beam properties can be included in either commercially available, but simple, finite element software or advanced finite element modelling tools. The only assumption required is that Euler-Bernoulli behaviour, where plane sections remain plane, must hold. A methodology for including rebar tension stiffening at elevated temperatures has been included based on modifying an ambient temperature model.

A series of numerical case studies are presented, comparing the results of the proposed beam formulation against finite element models using shell elements. Results between these models (which includes deflections, stresses, strains and neutral axis positions) typically differ by 0-5% when Euler-Bernoulli assumptions hold. Furthermore, case studies and experimental results from real fire tests in the literature were also analysed by the proposed formulation coupled with relatively simple finite element software. The deflections of structures in fire predicted by the proposed model are well within acceptable tolerances for fire engineering systems, and typically comparable to more complex models in the literature. The model developed has been used to investigate eleven different beams consisting of steel beams, concrete slabs and composite steel-concrete beams, along with conducting a series of parametric studies. With further research and the inclusion of three-dimensional behaviour the method could become a valuable tool for the analysis of structures in fire.