STRUCTURAL ASPECTS OF TOPOLOGY OPTIMIZATION IN 3D PRINTING OF CONCRETE



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Naser S. Alimrani - Marwah M. Thajeel - György L. Balázs

The 3D printing technologies have been initially developed in the 1980s. Currently, these technologies have become an integral part of modern product development and have been successfully applied in a wide range of industries including automotive manufacturing, biomedical, consumer, food, and construction. Since material efficiency is becoming a critical design driver in the construction industry, many strategies for improving material efficiency have been developed such as recycling materials, reusing components, reducing waste, extending life spans, etc. Furthermore, in the design phases, there are different design models that reduce the use of materials such as hollow-core and pre-stressing construction systems, or by applying concept of Topological Optimization. Topology optimization is a design method used in 3D printing technologies to reduce material without affecting the functionality of an object.

Keywords: 3D printing, topological optimization, structural aspects

1. INTRODUCTION

Material efficiency is becoming a critical design driver in the construction industry. While many strategies for improving material efficiency focus on the end of a building's lifecycle (recycling materials, reusing components, reducing waste, extending life spans, etc.), there is also great potential for reducing material use in the early design phases especially for materials that are difficult to recycle, such as concrete (Allwood et al., 2011). The usual means for achieving material reduction with concrete are hollow-core construction systems, pre-stressing, and the use of lightweight concrete. Computational methods, such as the optimization of size, shape, and topology, can also be used to ensure the efficient distribution of concrete for a given part. While significant material reduction can be achieved with these methods, the resulting geometries are often so intricate that fabrication becomes problematic (Dombernowsky and Søndergaard, 2011). Topology optimization is a powerful design tool aiming to maximize the performance of a structure by optimizing its material layout within certain conditions (Rong et al., 2022). This result is obtained by applying the concept that lies in the fact that no specified initial structural topology needs to be presumed a priori (Zhu et al., 2016). Several topology optimization techniques have been recently developed such as the homogenization method (Bendsøe and Kikuchi, 1988), the solid isotropic material with penalization (SIMP) (Zhou and Rozvany, 1991; Sigmund and Maute, 2013), the level set (Allaire et al., 2002; Wang et al., 2003), the bi-directional evolutionary structural optimization (BESO) (Xie and Steven, 1993; Huang and Xie, 2009), and the moving morphable components (MMC) (Guo et al., 2014). These techniques have been considerably applied in different fields such as mechanical engineering, advanced manufacturing, architectural design, and aerospace engineering. Finally, advanced manufacturing techniques such as 3D printing can be used to fabricate free-form designs generated by structural topology optimization (Rong et al., 2022).

The American Society for Testing and Materials (ASTM) International Committee F42 on AM technologies defines 3D printing as "the process of joining materials to make objects from 3D model data, usually layer upon layer" (ASTM F42, 2015). Topology optimization can be used as a design method to reduce material without affecting the functionality of an object. It is a process that promises almost no fabrication constraints, potentially enabling the production of topologically optimized complex geometries. Despite being one of the most demanding economic sectors in terms of material consumption, the construction industry has not yet adopted such design methods. This is generally because computational optimization algorithms produce solutions that are difficult to fabricate, especially at a large scale (Jipa et al., 2016). Furthermore, the conventional approach of casting concrete into a formwork limits geometrical freedom for the architects to build in various geometries, unless high costs are paid for bespoke formworks. Rectilinear forms not only limit creativity of the architects, but they are also structurally weaker than curvilinear forms owing to stress concentration (Nematollahi et al., 2017).

Regarding the environmental aspects, the current construction industry has serious issues with sustainability. In general, the current construction methods and materials are not environmentally friendly. The entire construction process, including off-site manufacturing, transportation of materials, installation and assembly, and on-site construction, emits huge amounts of greenhouse gases and consumes large quantities of energy (Yan et al., 2010). In addition, conventional concrete made by ordinary Portland cement (OPC) is not sustainable. Manufacture of OPC is highly energy and carbon intensive (Nematollahi et al., 2015). From another hand, astonishing data presented in Llatas's paper (Llatas, 2011) showed that the construction industry is responsible for generating approximately 80% of the total waste in the world. Application of three-dimensional (3D) printing techniques in concrete construction could solve the challenges stated in the literature. 3D printing technology

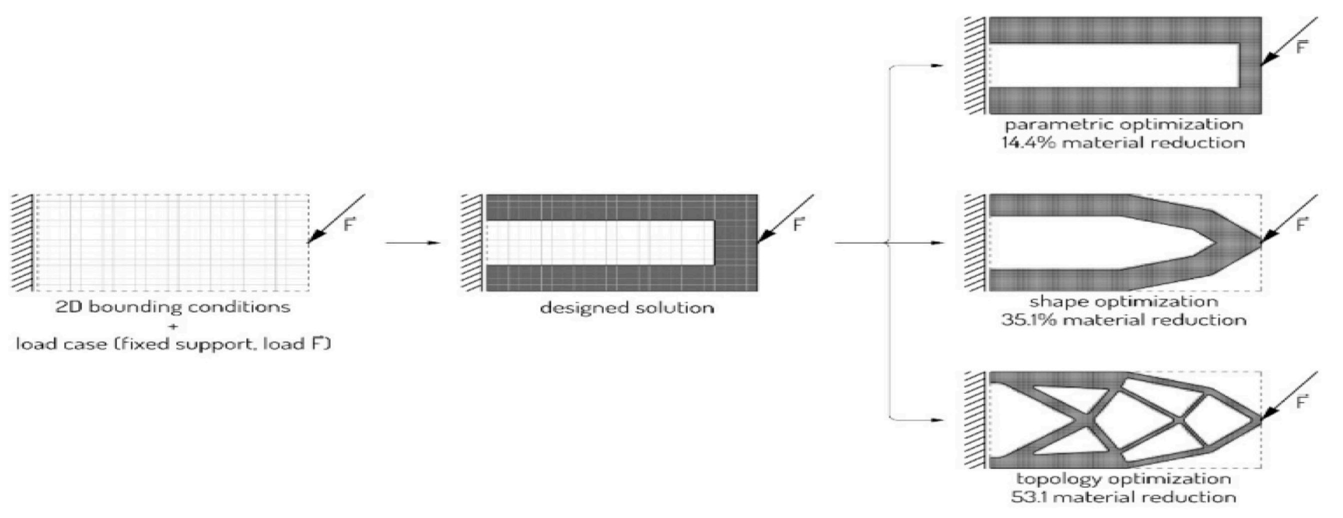


Figure 1: Different computational optimization processes: size, shape, and topology (Perrot et al., 2019)

is recently gaining popularity in construction industry. In the last few years, different 3D concrete printing (3DCP) technologies have been explored (Nematollahi et al., 2017).

2. TOPOLOGY OPTIMIZATION (TO)

Designing for efficient material distribution can be achieved through size, shape, or topology optimization processes. Size optimizations are contained within a fixed shape, while shape optimizations are constrained by a fixed topology (*Figure 1*).

Topology optimization processes are the most versatile and most broadly applicable of improving material distribution in terms of size, shape, and topology (Mijar et al., 1998).

Topology optimization is an iterative computational process that works within a confined, discretized space. For given loads and supports, the algorithm will refine material distribution to meet a prescribed set of performance targets. There are a number of different topology optimization algorithms, including Solid Isotropic Microstructure with Penalization (SIMP), Evolutionary Structural Optimization (ESO), and Topological Derivatives (Rozvany, 2009; Aremu, 2010). Despite the computational differences between these algorithms, they all produce a family of typical geometric features: interconnected networks of thin ribs and narrow tubular structures with dynamic changes in porosity (Jipa etl., 2016).

3. IMPORTANT DEVELOPMENTS OF TO

Three important developments of TO might directly influence the manufacturing and design process of 3D printed concrete structures, as follow (Vantyghem et al., 2018).

3.1 Compliance-Based Topology Optimization

The minimum compliance problem is one of the most well-known TO problems in literature. In this problem, the strain energy (also called compliance) is a global measure of the displacements. By minimizing the strain energy, the stiffness of the structure is maximized. Additionally, a volume constraint is added to act as an opposing restriction, and is comparable to a cost factor in reality. Mathematically, this material distribution problem is solved very efficiently using gradient-based optimizers coupled with adjoint sensitivity analysis (Vantyghem et al., 2018). In the example presented in Fig. 1, a benchmark problem and its optimal shape are presented.

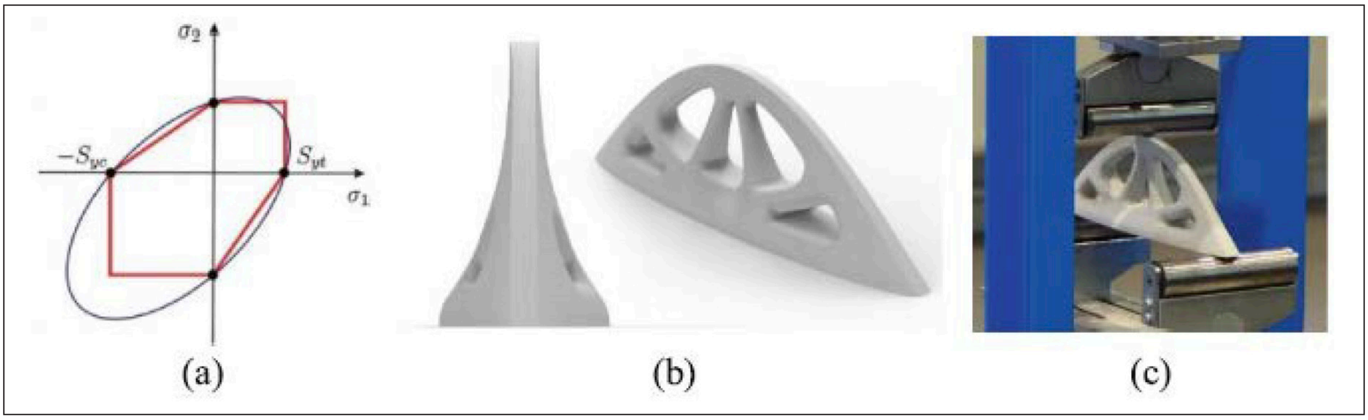
3.2 Stress-Based Topology Optimization

In the previous section, an optimal printing path and the positioning of the steel (chain) reinforcements was extracted from TO results. However, the use of steel reinforcements is today not commonly seen in 3D concrete printing processes. This lack of use of embedded tensile reinforcements hampers the fabrication of “functional” large-scale building components. A viable solution to this problem is studied, where carbon, glass and basalt fibers are being added to the cement mix before (or during) extrusion. Study showed that using reinforcing short fibers can result in materials that exhibit much higher flexural (up to 30 MPa) and compressive strength (up to 80 MPa). Additionally, “an alignment of the fibers, caused by the 3D printing extrusion process is observed, opening up the possibility to use the print path direction as a means to control fiber orientation within the printed structures” (Wu et al., 2016). The use of ultrahigh performance fiber-reinforced concrete was reviewed in some studies, and their superiority in comparison to conventional FRC structures proven (Yoo and Yoon, 2016).

The optimized structures are in fact oversized in the compression zones and would crack or break rather easily in the tensile zones. By introducing stress constraints in the topology optimization algorithm, optimal shapes can be generated which are optimized and take into account this strength asymmetry. Figure 2 illustrates this concept and presents a small concrete specimen which was optimized using Drucker–Prager yield criterion. For this case study, the maximum compressive strength was 60 MPa and the maximum tensile strength 15 MPa. The mathematical formulation was based on a study by (Bruggi and Duysinx, 2012) and optimized using special globally convergent version of MMA (Svanberg, 2002). In post-production, the resulting topology was reverse engineered in Fusion 360, and using Abaqus, a few manual design iterations were performed to further improve the model.

3.3 Multi-physics Topology Optimization

In this last example, traditional structural TO techniques are extended to include multi-physical requirements. By using



(a) (b) (c)

Figure 2: *(a) Mohr-Coulomb (red), Drucker-Prager (blue), (b) yield criterion optimized concrete specimen using stress-based TO, and (c) 3-point-bending test (Vantyghem et al., 2018)*

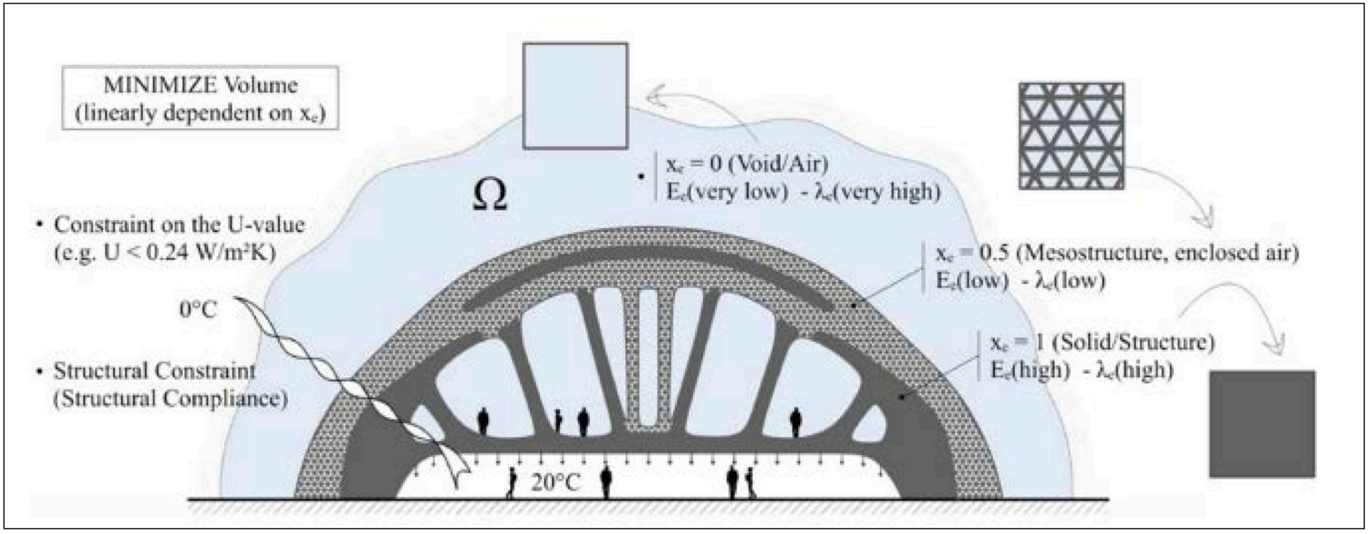
such multi-physics approach, an optimal design can be found which not only meets structural requirements, but where also the heat transfer characteristics of the structure are optimized (Bruggi and Taliercio, 2013; Vantyghem et al., 2017). In the case that is presented here, the thermal transmittance through the dome wall is minimized, the weight or volume of the structure is restricted, and the domain is subjected to gravity and surface loads. Similar to previous examples, the Young's modulus of each element depends on the density. However, in this example, the element's thermal conductivity is also calculated from this density. In contrast to previous studies, the design variables (element densities) have three optimal states. One state symbolizes the surrounding air (where, $x_e = 0$), another state represents the solid structure ($x_e = 1$), and finally, a third optimal state is created ($x_e = 0.5$) which symbolizes a thermally efficient mesostructure made from an intermediate density (Fig. 3). Originally, this idea was inspired by the infill pattern used in plastic 3D printing. However, the principle can be applied to concrete 3D printing as well, where one extrusion nozzle uses plain or fiber-reinforced concrete, and another nozzle could use a thermally efficient substitute such as "Foamcrete" (Othuman, 2013).

4. COMPUTATIONAL MODELING AND OPTIMIZATION

Computational modeling and topology optimization techniques provide for the possibility to design and optimize the 3 D printed cement-based element on a multitude of scales and materials and to achieve more sustainable and cost-effective designs. Topology optimization consists of the discretization of an object or structure into small elements and optimization of the material composition, volume fractions, and spatial distribution within each element to achieve functionally graded objects or structures with desired properties and/or functional performance. New computational frameworks for topology optimization with microstructures that supports design spaces of multiple dimensions are emerging and are being combined with 3 D printing in many fields (Zhu et al., 2017; Liu et al., 2019; Martens, et al., 2018; Kazakis et al., 2017; Nguyen et al., 2019). Another application of topology optimization techniques for concrete concerns the optimization of the cement binder itself by tuning the internal topology at different scales. Advances and challenges in this area are discussed in (Martens, et al., 2018).

Despite the remarkable achievements in the field of structural topology optimization, there still remain many challenging issues which require further research. For example, an interesting issue is how to make the design domain automatically and intelligently evolve during the form-finding process. In case that the resolution is specified, the larger the design space, the higher the computational cost. The design space cannot be excessively large due to the limit of computing resources. In the conventional topology optimization, the predefined design space keeps fixed. However, it is desirable to update or reshape the design space due to the following reasons. First, in many optimization problems, the designer cannot predefine an optimized design space that guarantees a satisfactory

Figure 3: Multi-physics topology optimization of a dome structure where the element density variable has three optimal states. xe = 0 (void), xe = 0.5 (mesostructured), and xe=1 (solid) (Vantyghem et al., 2018)



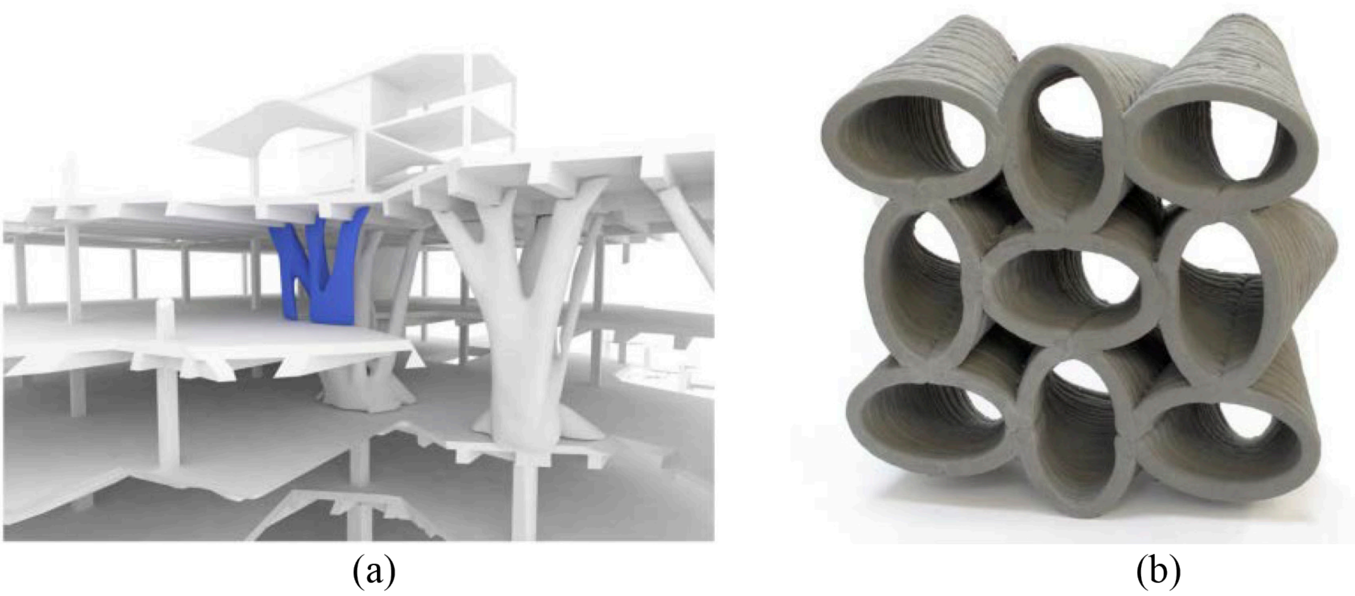


Figure 4: *Examples for large-scale application, a) Architectural context for the multifunctional wall element, and b) Concrete 3D printed acoustic damping wall element (Gosselin et al., 2016)*

solution. Second, in transdisciplinary form-finding problems such as biomechanical morphogenesis, the evolution of the design space is necessary to mimic the real biological growth in nature. A grid-based method was proposed to adjust the design space layer by layer (Kim and Ewak, 2002; Jang and Ewak, 2006). However, the grid is predefined and fixed, and the expansion of the design space features low efficiency.

There is a lack of an adequate method for updating the design domain during the form-finding process. Such a method should help broaden the application of structural topology optimization in many disciplines. Rong et al. (2022) proposed a subdomain-based method that performs topology optimization in an adaptive design domain (ADD). A subdomain based parallel processing strategy that can vastly improve the computational efficiency is implemented. In the ADD method, the loading and boundary conditions can be easily changed in concert with the evolution of the design space. Through the automatic, flexible, and intelligent adaptation of the design space, this method is capable of generating diverse high-performance designs with distinctly different topologies. Finally, this approach might help broaden the applications of structural topology optimization (Rong et al., 2022).

5. APPLICATIONS OF TO

3D printing is a disruptive technology which offers novel solutions that reconciliate non-standard shapes, and low costs. Targeting unprecedented efficiency and/or multifunctionality through geometry can push the boundaries of the design space available for engineers, architects, and designers. Additional functions can be embedded in the structural parts, i.e., not only mechanical properties but also thermal insulation, soundproofing, etc. Two examples for large-scale application are presented in this paper. Both cases are relevant examples for demonstrating feasibility of the technology developed for application in architecture and construction (Gosselin et al., 2016).

5.1 Multifunctional wall element

This element was designed within a context of structural rehabilitation, starting from the damaged structure, i.e., one floor and its upper level without any structural support. The element was designed with the aim of optimizing what would become the external supporting wall, as shown on Fig. 4 a. The element consists in an absorptive formwork to be filled either with ultra-high performance fibre-reinforced concrete on structural parts or with an insulating material such as foam for thermal insulation. Some parts are also left intentionally empty to be able to host pipes or electrical wires. The formwork has two column-like parts, linked to two straight plates in-between which waves a bi-sinusoidal shell (Gosselin et al., 2016).

5.2 Acoustic damping wall element

Another example is the following element which was designed as a generic element both structural and acoustic performance, to be assembled alongside with others in order to form a complete wall. The different hole geometries could provide enhanced soundproofing properties to the element, by damping the acoustic waves passing through depending on the geometry of the wall cells and material properties. The produced element sizes roughly 650 mm × 650 mm × 300 mm and is shown in Fig. 4 b. It was printed in 2 h (26 layers), orthogonally to the plan of the wall in order to allow lace support (Gosselin et al., 2016).

6. CONCLUSIONS

Topology optimization is a powerful design tool aiming to maximize the performance of a structure by optimizing its material layout by applying an approach that no specified initial structural topology needs to be presumed a priori. Several topology optimization techniques have been recently developed and considerably applied in different fields such as mechanical engineering, advanced manufacturing, architectural design, and aerospace engineering. Finally, advanced manufacturing techniques such as 3D printing can be used to fabricate free-form designs generated by structural topology optimization.

Despite being one of the most demanding economic sectors in terms of material consumption, the construction industry has not yet adopted such design methods. This is generally because computational optimization algorithms produce solutions that are difficult to fabricate, especially at a large scale. The conventional approach of casting concrete into a formwork limits geometrical freedom for the architects to build in various geometries unless high costs are paid for bespoke formworks. Rectilinear forms not only limit creativity of the architects, but they are also structurally weaker than curvilinear forms owing to stress concentration.

At the current study, the authors review the aspects of topology optimizations in concrete alongside with its potential structural, economic, and environmental impacts.

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REFERENCES

Allaire, G. Jouve, F. Toader, A.M. (2002), “A level-set method for shape optimization”, *C. R. Math*. 334 (12) 1125–1130. https://doi.org/10.1016/s1631-073x(02)02412-3

Allwood, J.M. Michael F.A. Timothy G.G. and Ernst W. (2011), “Material efficiency: A white paper.” *Resources, Conservation and Recycling* 55, (2011), no. 3 362–381. https://doi.org/10.1016/j.resconrec.2010.11.002

Aremu, A. Ashcroft, I. Hague, R. Wildman, R. and Tuck, C. (2010), “Suitability of SIMP and BESO topology optimization algorithms for additive manufacture.” *In Twenty First Annual International Solid Freeform Fabrication Symposium*, Austin, pp. 679– 692. 2010.

ASTM F42. (2015), “Standard Terminology for Additive Manufacturing Technologies”. West Conshohocken: ASTM International, 2015.

Bendsøe, M.P. Kikuchi, N. (1988), “Generating optimal topologies in structural design using a homogenization method, *Computer Methods in Applied Mechanics and Engineering*. 71 (2) 197–224. https://doi.org/10.1016/0045-7825(88)90086-2

Bruggi, M. Duysinx, P. (2012), “Topology optimization for minimum weight with compliance and stress constraints”. *Struct. Multidiscip. Optim*. 46(3), 369–384 (2012). https://doi.org/10.1007/s00158-012-0759-7

Bruggi, M. Taliercio, A. (2013), “Design of masonry blocks with enhanced thermomechanical performances by topology optimization”. *Constr. Build. Mater*. 48, 424–433. https://doi.org/10.1016/j.conbuildmat.2013.07.023

Gosselin, C. Duballet, R. Roux, P. Gaudillière, N. Dirrenberger, J. and Morel, P. (2016), “Large-scale 3D printing of ultra-high-performance concrete–a new processing route for architects and builders”. *Materials and Design*, 100, pp.102-109. https://doi.org/10.1016/j.matdes.2016.03.097

Guo, X. Zhang, W. Zhong, W. (2014), “Doing topology optimization explicitly and geometrically—a new moving morphable components-based framework”, J. *Appl. Mech*. 81 (8) 081009. https://doi.org/10.1115/1.4027609

Huang, X. Xie, Y.M. (2009), “Bi-directional evolutionary topology optimization of continuum structures with one or multiple materials”, *Comput. Mech*. 43 (3) 393–401. https://doi.org/10.1007/s00466-008-0312-0

Jang, I.G. Kwak, B.M. (2006), Evolutionary topology optimization using design space adjustment based on fixed grid, *Internat. J. Numer. Methods Engrg*. 66 (11) (2006) 1817–1840. https://doi.org/10.1002/nme.1607

Jipa, A. Bernhard, M. Meibodi, M. and Dillenburger, B. (2016), “3D-printed stay-in-place formwork for topologically optimized concrete slabs”. *In Proceedings of the 2016 TxA Emerging Design+ Technology Conference*, pp. 97-107.

Kazakis, G. Kanellopoulos, I. Sotiropoulos, S. Lagaros, N. (2017), “Topology optimization aided structural design: interpretation, computational aspects and 3D printing”, Heliyon 3, e00431. https://doi.org/10.1016/j.heliyon.2017.e00431

Kim, I.Y. Kwak, B.M. (2002), “Design space optimization using a numerical design continuation method”, Internat. *J. Numer. Methods Engrg*. 53 (8) (2002) 1979–2002. https://doi.org/10.1002/nme.369

Liu, H. Du, T. Krishnan, N. Li, H. Bauchy, M. (2019), “Topological optimization of cementitious binders: advances and challenges”. *Cem. Concr. Compos*. 101 (2019) 5–14. https://doi.org/10.1016/j.cemconcomp.2018.08.002

Llatas C. (2011), “A model for quantifying construction waste in projects according to the European waste list”. *Waste Management*, 6(31):1261–1276. https://doi.org/10.1016/j.wasman.2011.01.023

Martens, P. Mathot, M. Bos, F. Coenders, J. (2018), “Optimizing 3D Printed Concrete Structures Using Topology Optimization, Springer International Publishing,” *Cham*, 2018, pp. 301–309. https://doi.org/10.1007/978-3-319-59471-2_37

Mijar, A.R. Colby C.S, Jasbir S.A. and Iku K. (1998), “Continuum topology optimization for concept design of frame bracing systems.” *Journal of Structural Engineering* 124, no. 5 (1998): 541–550. https://doi.org/10.1061/(asce)0733-9445(1998)124:5(541)

Nematollahi B. Sanjayan J. and Shaikh F.U.A. (2015), “Synthesis of heat and ambient cured one-part geopolymer mixes with different grades of sodium silicate. Ceramics International”. 41(4): 5696–5704. https://doi.org/10.1016/j.ceramint.2014.12.154

Nematollahi, B. Xia, M. and Sanjayan, J. (2017), “Current progress of 3D concrete printing technologies”. In ISARC. *Proceedings of the International Symposium on Automation and Robotics in Construction* Vol. 34. IAARC Publications. https://doi.org/10.22260/isarc2017/0035

Nguyen, K.C. Tran, P. Nguyen, H. (2019), “Multi-material topology optimization for additive manufacturing using polytree-based adaptive polygonal finite elements”, Autom. Constr. 99 (2019) 79–90. https://doi.org/10.1016/j.autcon.2018.12.005

Othuman M.M. (2013), “An experimental investigation on thermal conductivity of lightweight Foamcrete for thermal insulation”. *Jurnal Teknologi* 63(1). https://doi.org/10.11113/jt.v63.1368

Perrot, A. ed. (2019), “3D printing of concrete: state of the art and challenges of the digital construction revolution”. https://doi.org/10.1002/9781119610755

Rong, Y., Zhao, Z.L., Feng, X.Q. and Xie, Y.M. (2022), “Structural topology optimization with an adaptive design domain”. *Computer Methods in Applied Mechanics and Engineering*, 389, p.114382. https://doi.org/10.1016/j.cma.2021.114382

Rozvany, G. (2009), “A critical review of established methods of structural topology optimization.” *Structural and Multidisciplinary Optimization* 37, no. 3 (2009): 217–237. https://doi.org/10.1007/s00158-007-0217-0

Sigmund, O. Maute, K. (2013), “Topology optimization approaches”, *Structural and Multidisciplinary Optimization*. 48 (6) 1031–1055. https://doi.org/10.1007/s00158-013-0978-6

Søndergaard, A. and Dombernowsky, P. (2016), “Unikabeton Prototype.” In Fabricate: Making Digital Architecture, eds. Ruairi Glynn and Bob Sheil. *Cambridge, Ontario: Riverside Architectural Press*. 2011. https://doi.org/10.2307/j.ctt1tp3c6d.14

Svanberg, K. (2002), “A class of globally convergent optimization methods based on conservative convex separable approximations”. *SIAM J. Optim*. 12(2), 555–573 (2002). https://doi.org/10.1137/s1052623499362822

Vantyghem G. Boel V. De Corte W. et al. (2018), “Compliance, Stress-based and Multi-physics topology optimization for 3D-Printed concrete structures”, in *RILEM International Conference on Concrete and Digital Fabrication*, pp. 323–332, 2018. https://doi.org/10.1007/978-3-319-99519-9_30

Vantyghem, G. Steeman, M. De Corte, W. Boel, V. (2017), “Design of Cellular materials and mesostructures with improved structural and thermal performances”. In: *Advances in Structural and Multidisciplinary Optimization*, pp. 1983–1996. https://doi.org/10.1007/978-3-319-67988-4_147

Wang, M.Y. Wang, X. Guo, D. (2003), “A level set method for structural topology optimization”, *Computer Methods in Applied Mechanics and Engineering*. 192 (1–2) 227–246. https://doi.org/10.1016/s0045-7825(02)00559-5

Wu, P. Wang, J. Wang, X. (2016), “A critical review of the use of 3-D printing in the construction industry”. *Autom. Constr*. 68, 21–31 (2016). https://doi.org/10.1016/j.autcon.2016.04.005

Xie, Y.M. Steven, G.P. (1993), “A simple evolutionary procedure for structural optimization”, *Comput. Struct*. 49 (5) 885–896. https://doi.org/10.1016/0045-7949(93)90035-c

Yan H. Shen Q. Fan L.C. Wang Y. and Zhang, L. (2010), “Greenhouse gas emissions in building construction: A case study of One Peking in Hong Kong”. *Building and Environment*, 45(4):949–55. https://doi.org/10.1016/j.buildenv.2009.09.014

Yoo, D. Yoon, Y. (2016), “A review on structural behavior, design, and application of ultra-high-performance fiber-reinforced concrete”. *Int. J. Concr. Struct. Mater*. 10(2), 125–142 (2016). https://doi.org/10.1007/s40069-016-0143-x

Zhou, M. Rozvany, G. (1991), “The COC algorithm, Part II: topological, geometrical and generalized shape optimization”, *Computer Methods in Applied Mechanics and Engineering*. 89 (1–3) 309–336. https://doi.org/10.1016/0045-7825(91)90046-9

Zhu, B. Skouras, M. Chen, D. Matusik W. (2017), "Two-scale topology optimization with microstructures", *ACM Trans*. Graph. 36, (4) 1 (2017). https://doi.org/10.1145/3072959.3126835

Zhu, J., Zhang, W. and Beckers, P., 2009. Integrated layout design of multi-component system. *International journal for numerical methods in engineering*, 78(6), pp.631-651. https://doi.org/10.1002/nme.2499

Zhu, J.H., Zhang, W.H. and Xia, L. (2016), "Topology optimization in aircraft and aerospace structures design". *Archives of Computational Methods in Engineering,* 23(4), pp.595-622. https://doi.org/10.1007/s11831-015-9151-2

Naser S. Alimrani (1989), PhD Candidate at the Department of Construction Materials and Technologies, Budapest University of Technology and Economics. His main fields of research interest are fire design, behaviour of concrete, shear performance, failure modes of concrete at high temperatures, hollow core slabs, bond properties, bond stress-slip relationships, 3D printing concrete, sustainability, and construction management. Member of the Hungarian Group of ***fib***, and member of the YMG in the ***fib.***

Marwah M. Thajeel (1991), *PhD* student at the Department of Construction Materials and Technologies, Budapest University of Technology and Economics. Finished her bachelor (2012) in Civil Engineering at College of Engineering, Al-Muthanna University in Iraq and finished her master studies (2020) Master of Science in Structural Engineering at College of Engineering, Al-Qadisiyah University in Iraq. Research areas: Reinforced Concrete, Shear Strengthening, Fiber Reinforced Polymers, Fiber Reinforced Concrete. Member of the Hungarian Group of ***fib***.

György L. Balázs (1958), Civil Engineer, PhD, Dr.-habil., Professor of structural engineering at the Department of Construction Materials and Technologies of Budapest University of Technology and Economics (BME). His main fields of activities are experimental investigation and modeling of RC, PC, FRC, FRP, HSC, HPC, LWC, fire resistance and fire design, durability, sustainability, bond and cracking. He is chairman of several commissions and task groups of ***fib***. He is president of Hungarian Group of ***fib***, Editor-in-chief of the Journal "Concrete Structures". He was elected as President of ***fib*** for the period of 2011-2012. Since then, he is Honorary President of ***fib***. Chairman of ***fib*** Com 9 Dissemination of knowledge.