***Review Article***

# A Bibliometric Review Approach to the Ultrasonic Pulse Velocity and Compressive Strength


**ABSTRACT**

Bibliometric analysis is an interesting statistical tool for studying the state of the art in any field of scientific knowledge and identifying the information needed for various purposes. Therefore, in this paper we uncover the synthesis between Ultrasonic Pulse Velocity (UPV) and Compressive Strength (CS) parameters, also to classify research trends knowledge gaps that can be treated in future research on UPV-CS. The maps of publication are made by a Bibliometric analyzes in order to determine the use of these techniques for the control of cementitious structures in the research subjects of the two topics separately and jointly on the basis of the identified academic publications from Scopus (i.e. 3018 CS Articles, 126 UPV Articles and 82 UPV-CS Articles). This comparison of two parameters that describe the durability of materials used in literature reviews allows the authors to focus on identifying the most influential contributors to research advances in Civil Engineering field.



*Keywords: Ultrasonic Pulse Velocity (UPV); Compressive Strength (CS); Literature review; Bibliometric review.*


## 1. INTRODUCTION

"Nondestructive testing techniques, particularly the UPV and rebound hammer, are performed to evaluate the quality of a concrete structure across the world because they enable the examination of structures without damaging them. UPV can assess the homogeneity of concrete and properties that change with time" [1]. "New developments include air-coupled and laser-generated measurement equipment used as an ultrasonic technique for evaluation of reinforced concrete structures, [2]describe an automated device utilizing air coupled transducers". "It generates Rayleigh waves on a single concrete surface and measures the dispersive propagation velocity and attenuation, which can then be correlated to concrete properties. The ultrasonic pulse velocity (UPV) measurement can be utilized for the determination of concrete uniformity, cracks or voids' presence, changes in properties with time. As the amount of DOTP in the concrete increases, the ultrasonic pulse velocity of the concrete decreases. It can be said that this is due to the porous structure of DOTP-reinforced concrete" [3]. "The dramatic drop in ultrasonic pulse velocity and the porous structure of DOTP-reinforced concrete is another indication that DOTP-reinforced concrete has good quality" [3]. "When UPV of cementations structures is higher, the structures are classified as good and high-quality concrete grade" [4]. "Concrete Compressive Strength by Means of Ultrasonic Pulse Velocity and Modul of Elasticity" [5]. [6] Revealed that "the use of carbon nanostructures of slag and cement improves the durability of concrete pavements". "Effect of silica fume on mechanical properties of high-strength concrete" [7]. This article is ordered as follows. In Part 2, previous work related to CS and UPV topics is summarized. In Section 3, mixed-review methodology used in this research is illustrated in detail. Subsequently, the results obtained and the conclusions are described in section 4.

## 2. PREVIOUS WORK

This section discusses existing literature review on CS and UPV to clarify the need of the mixed review on UPV for CS presented in this paper.

### 2.1. CS-related review

In 1992 [8] showed the first work of including metakaolin in concrete which shows very significant improvements in strength. The results of their work indicated that the optimal level of metakaolin replacement is between 5 and 10%. The use of adjuvants and metakaolin in high strength concrete has been studied by other researchers [9] [10]. [11] obtained compressive and 28-day strengths of the order of 106 N/mm2 for concrete containing metakaolin (10%) and with a superplasticizer. [8] and [10] obtained conclusions on the compressive strength in particular on the effect of: Methodology of the test mixture, approach of the mix design, variations of the composition of the cement. [12] Have examined the compressive strength of the mortar by adding Silica Fume in the paste, the results obtained show that the porosity of the mortar decreased in the presence of silica, while the porosity increased in the case of the paste due to the reaction of SF with alkalis. Thus, the fine particles of Silica Fume penetrate into the pores and increase the compactness.

### 2.2. UPV-related review

Ultrasonic pulse velocity test is a non-destructive testing technique and very sensitive technique. It can be used to approximately evaluate the internal structural of a material. The main factors influencing UPV results can be concluded as sizes of aggregate, ages of concrete, test temperatures, moisture content of specimens, types of cement, shapes and sizes of specimens, and curing conditions. For this, it used to interpret the homogeneity, quality, cracks, voids, and anomalies of concrete. UPV used also to evaluate Self-healing concrete, it observed that a 1% greater water content of concrete specimens increases UPV results by 160 m/s. The results of UPV will increase by 34 m/s on average when temperature increases by 10°C [13]. For the study of the performance of concrete with PVC fibers, [14] Estimated the quality of concrete made with PVC fibers using the UPV controller. [14] Observed that the UPV of the specimens decreased with increasing PVC fiber content. This decrease is not considered to be due to porosity or internal defects in the concrete. In fact, the plastic has the ability to pick up pulse waves, which may be the main cause of the decrease in UPV values of concrete[15].When the UPV values are between 3500 and 4500m/s, the concrete is termed as good concrete and when the values are more than 4500 m/s, the concrete is considered as the superior one. The maximum and minimum UPV values of PVC fiber concrete are between 4350 and 4640 m/s. UPV is also a means to study the behavior of self-compacting high volume fly ash (HVFA) based on high volume fly ash. This test also offers the idea of the different defaults present inside the concretes by electron wave transfer [16]. In general, the UPV values decrease with increasing proportion of FA in SCC mixtures. However, with the increase in the release times, the UPV values were found to be increased in the same way as the compressive strength [17]. Table 1 tabulates existing reviews with respect to UPV and CS.

**Table 1. Summary of literature review on CS, UPV**

| *Review article* | *Research method* | *Research theme* | |
|---|---|---|---|
| | | *CS* | *UPV* |
| [18] | *Systematic review* | *x* | |
| [19] | *Systematic review* | *x* | |
| [20] | *Critical review* | *x* | |
| [21] | *Critical review* | *x* | |
| [22] | *Critical review* | *x* | |
| [23] | *Critical review* | *x* | |
| [24] | *Bibliometric analysis* | *x* | |
| [25] | *Systematic review* | | *x* |

## 3. RESEARCH METHODOLOGY

The objective of this research is to synthesize the domain knowledge and to identify the research needs and future research direction within the field of UPV-CS in the investigation of cementitious materials for construction. Toward this objective, a "mixed-review method" is employed in this study. In general, this method consists of quantitative review (i.e., Bibliometric approach) and qualitative review (i.e., systematic approach), so that it is capable of eliminating biased conclusion and subjective interpretation while providing an in-depth understanding of domain knowledge and research trends [26]. The proposed mixed examination method used in this paper is conducted in three phases (Figure 1). Phase 1 involves a bibliometric analysis of the UPV literature and the CS literature. The aim of this step is to discover the knowledge domains of these two topics (UPV and CS respectively). The results of these two topics are summarized in this phase. The second phase consists of a bibliometric analysis of BIM for CSO. Based on the knowledge areas identified for UPV and CS individually, this phase identifies the joint research priorities of UPV and CS (i.e., UPV for CS). Phase 3 is a systematic review of research on UPV applications in the CS. In this step, academic articles on UPV for CS are grouped by research topic in a systematic way.

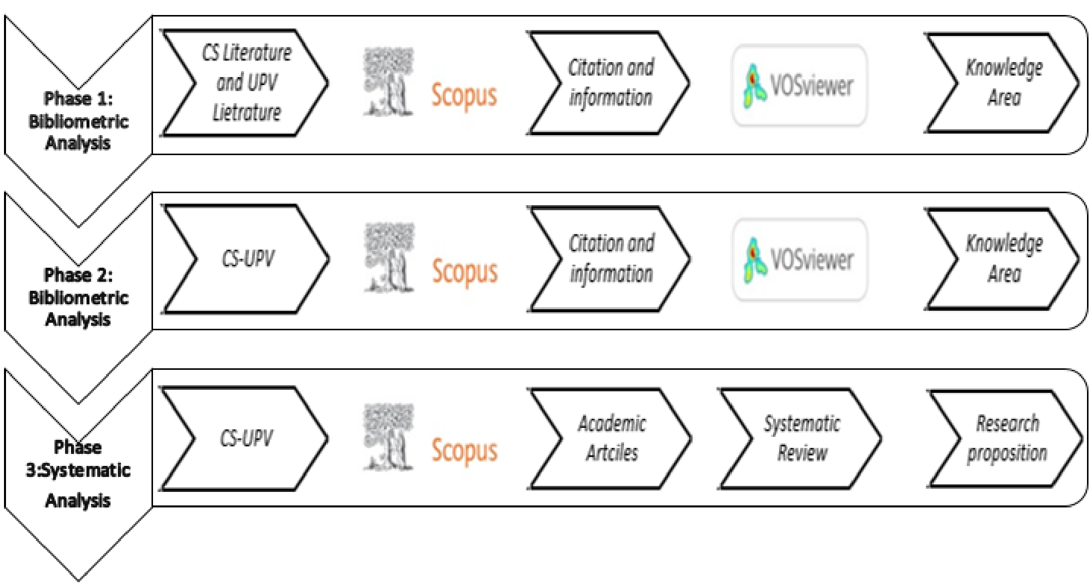


**Fig1. Overview of methodology research**

## 4. RESULTS AND FINDINGS

### 4.1. Overview

The keyword search strategies listed in Table 2 were employed to identify relevant academic articles and their journals and conferences, which have been partially summarized in Table 3. Particularly, the number of resulting UPV publications for construction is quite low due to the use of UPV to investigate the durability of cementitious materials as keyword to search the academic database. As shown in Table 2, the majority of academic publications on CS and UPV are found in the top journals in the field, Construction and Building Materials, Cement and Concrete Composites, Materials, Journal of Building Engineering. Among these journals, Construction and Building Materials is the journal that includes the most publications on these three area (CS, UPV and UPV-CS)

**Table 2. Literature search strategies and their results.**

| *Topic* | *Search keywords* | *Time period* | *Number of results* |
|---|---|---|---|
| *Compressive Strength* | *"Compressive strength" AND "Concrete" AND "Cement" AND "Mortar"* | *Jan, 2000- Dec, 2021* | *3057* |
| *Ultrasonic pulse velocity* | *"ultrasonic pulse velocity" AND "Concrete" AND "Cement" AND "Mortar"* | *Jan, 2000- Dec, 2021* | *126* |
| *Compressive Strength and Ultrasonic pulse velocity* | *"Compressive strength" AND "ultrasonic pulse velocity" AND "Concrete" AND "Cement" AND "Mortar"* | *Jan, 2000- Dec, 2021* | *82* |
| *Compressive Strength and Ultrasonic pulse velocity* | *Manual screening based on the 113 studies in Stage 2* | *Jan, 2000- Dec, 2021* | |

**Table 3. Identified academic journals and number of articles from Jan, 2000 to Dec, 2021**

| *Journal/conference title* | *Number of articles* | | |
|---|---|---|---|
| | *Compressive Strength (CS)* | *Ultrasonic pulse velocity (UPS)* | *CS and UPV* |
| *Advanced Materials Research* | *58* | *0* | *1* |
| *Aip Conference Proceedings* | *29* | *2* | *2* |
| *American Concrete Institute ACI Special Publication* | *61* | *2* | *2* |
| *Applied Sciences Switzerland* | *21* | *1* | *1* |
| *Case Studies In Construction Materials* | *16* | *1* | *1* |
| *Cement And Concrete Composites* | *66* | *6* | *1* |
| *Cement And Concrete Research* | *73* | *2* | *0* |
| *Construction And Building Materials* | *397* | *20* | *18* |
| *Data In Brief* | *4* | *1* | *1* |
| *European Journal Of Environmental And Civil Engineering* | *12* | *3* | *2* |
| *Iop Conference Series Earth And Environmental Science* | *32* | *1* | *3* |
| *Iop Conference Series Materials Science And Engineering* | *73* | *5* | *0* |
| *Journal Of Building Engineering* | *36* | *2* | *2* |
| *JurnalTeknologi* | *7* | *4* | *4* |
| *Key Engineering Materials* | *41* | *4* | *3* |
| *Materials* | *86* | *7* | *6* |
| *Materials And Structures Materiaux Et Constructions* | *26* | *3* | *3* |
| *Structural Concrete* | *16* | *2* | *2* |
| *Sustainable Construction Materials And Technologies* | *11* | *1* | *1* |

Figure 2 shows how the number of publications on the three topics under review (CS, UPV and UPV-CS) varies each year. Publications on SC showed an overall upward trend since 2000, while the curve for BIM publications showed a rapid increase since 2003. The number of publications on UPV-CS is relatively small, compared with the number of publications on both CS and UPV, of which there were 21 in 2021.The trend shows a growth state, indicating an increasing attention to the application of UPV to control the strength of construction materials. The rationale for using UPV to determine the strength of materials research occurred in 2016, when the number of publications exceeded 10 for the first time. This trend has continued from 2020.

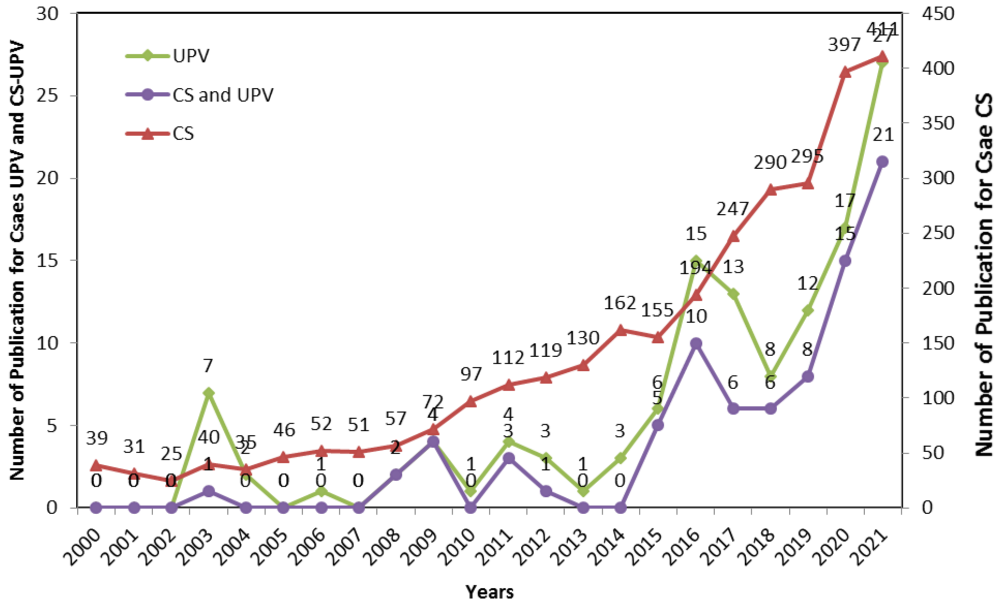


**Fig 2. Yearly literature distribution for the published papers targeted on CS, UPV and UPV-CS (Jan 2000 to Dec 2021).**

### 4.2. Bibliometric analysis of UPV-CS

Interestingly, less attention has been directed toward UPV-CS. Only 82 results were obtained for this research topic from the Scopus database, which is relatively fewer in comparison with CS (3018). In this section, 82 publications related to this topic were analyzed using a Bibliometric approach, with the intention of exploring the current research patterns in UPV-CS. The keywords of 82 academic publications on UPV-CS were fed into VOSviewer to generate a co-occurrence graph of author keywords. The minimum number of time that a keyword must occur to be included was set to 3. Of the 277 keywords, 22 met the threshold. The cluster view of author keywords in the VOSviewer is shown in Figure 3; the bigger the circle indicates the more times the item occurs in the literature [27]. The detailed quantity information for each of the keywords of UPV-CS literature is tabulated in Table 4. As shown in Figure 3 and Table 4, other than the keywords UPV-CS, the occurrence of keywords is evenly distributed. Most of the publications pertaining to UPV-CS have been published in the period after 2015, indicating regency compared to studies exploring either of the two topics (CS and UPV) separately. Keywords such as Strength, Flexural strength, Portland limestone cement, Cement and Geopolymer form the biggest cluster in Figure 3, which indicates that material Strength is a major topic in research on UPV-CS

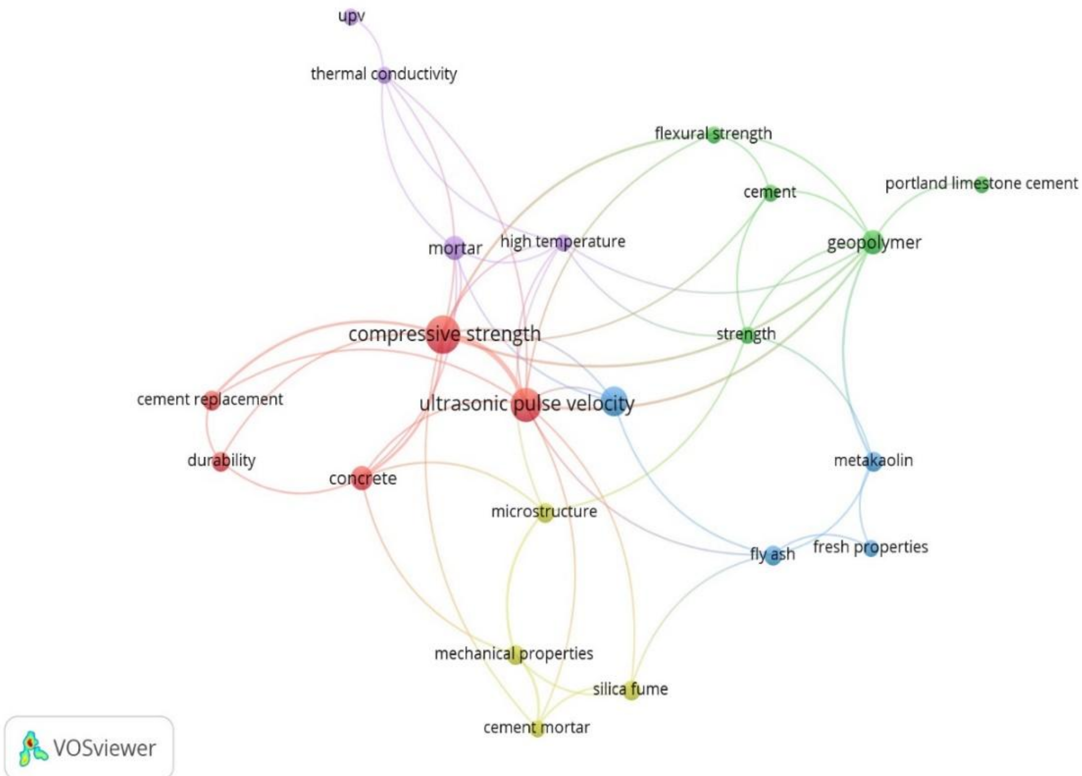


**Fig 3. Author keywords co-occurrence UPV-CS.**

**Table 4. Top keywords for UPV-CS literature.**

| *keyword* | *Number* | *occurrences* | *total link strength* |
|---|---|---|---|
| *Compressive strength* | *62* | *15* | *22* |
| *Ultrasonic pulse velocity* | *42* | *12* | *18* |
| *Self-healing* | *9* | *9* | *4* |
| *Concrete* | *26* | *6* | *7* |
| *Geopolymer* | *2* | *6* | *11* |
| *Mortar* | *47* | *6* | *5* |
| *Cement replacement* | *4* | *4* | *4* |
| *Durability* | *11* | *4* | *3* |
| *Fly ash* | *10* | *4* | *5* |
| *Mechanical properties* | *10* | *4* | *6* |
| *Metakaolin* | *7* | *4* | *5* |
| *Microstructure* | *7* | *4* | *5* |
| *Silica fume* | *7* | *4* | *4* |
| *Cement* | *26* | *3* | *4* |
| *Cement mortar* | *4* | *3* | *5* |
| *Flexural strength* | *3* | *3* | *5* |
| *Fresh properties* | *3* | *3* | *2* |
| *High temperature* | *3* | *3* | *7* |
| *Portland limestone cement* | *3* | *3* | *1* |
| *Strength* | *3* | *3* | *5* |
| *Thermal conductivity* | *3* | *3* | *5* |
| *UPV* | *3* | *3* | *1* |

Citation information for the 82 documents was analyzed to reveal the significant publications in the field of UPV-CS. The citation analysis results are shown in Table 5. The 10 most-cited papers and the number of time search article was cited is listed in Table 5. The citation analysis was conducted to identify the research distribution across the world. VOSviewer provides a function to categorize the documents and their citations based on the country of publication, which can be seen in Fig. 4. The minimum number of documents from each country was set at 3; therefore, 3 countries met the threshold out of 32 possible countries). It is obvious that Malaysia and Turkey contributes the most in terms of UPV-CS, however, the citation number of Malaysia is relatively low. India has the third most studies concentrating on this specific topic. On the contrary Poland, United States and Canada are very prominent in the number of citations.

**Table 5. Most-cited academic publications regarding for UPV-CS.**

| *N°* | *Document* | *Title* | *Cited times* |
|---|---|---|---|
| *1* | [28] | *Effect of rice husk ash on the strength and durability characteristics of concrete* | *202* |
| *2* | [29] | *Concrete using agro-waste as fine aggregate for sustainable built environment – A review* | *95* |
| *3* | [30] | *An investigation on effect of partial replacement of cement by waste marble slurry* | *87* |
| *4* | [31] | *Properties of self-compacting mortars with binary and ternary cementitious blends of fly ash and metakaolin* | *77* |
| *5* | [32] | *Freeze-thaw resistance of blended cements containing calcined paper sludge* | *71* |
| *6* | [33] | *Thaumasite form of sulfate attack in limestone cement mortars: A study on long term efficiency of mineral admixtures* | *53* |
| *7* | [34] | *The use of high calcium wood ash in the preparation of Ground Granulated Blast Furnace Slag and Pulverized Fly Ash geopolymers: A complete microstructural and mechanical characterization* | *51* |
| *8* | [35] | *Mathematical model for the prediction of cement compressive strength at the ages of 7 and 28 days within 24 hours* | *46* |
| *9* | [36] | *Long term behavior of Portland limestone cement mortars exposed to magnesium sulfate attack* | *42* |
| *10* | [31] | *Effects of marble powder and slag on the properties of self compacting mortars* | *38* |

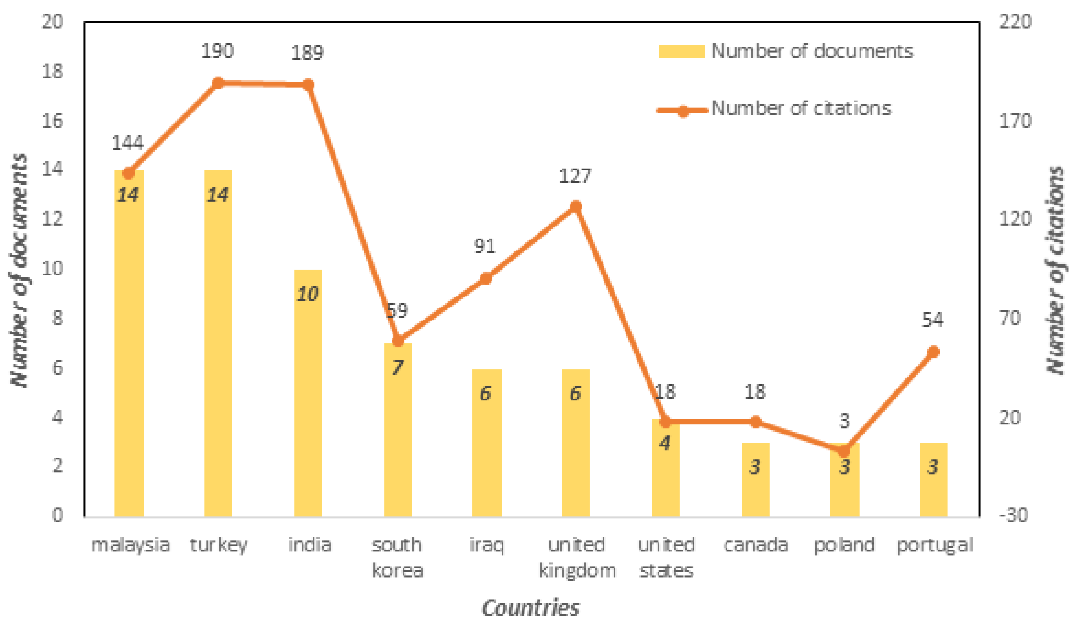


**Fig 4. Documents and citation country/region distribution.**

## 5. CONCLUSION

This paper attempts to present the studies on the use of CS compressive strength of materials and UPV ultrasonic pulse velocity used in civil engineering. A mixed review was conducted to develop the scientific maps of CS, UPV and UPV-CS. In this review, a quantitative review is conducted using VOSviewer on the topic of CS for UPV from the literature retrieved from Scopus.
This search has some limitations. Namely, the data are extracted from a single database due to the consistent requirements developed by VOSViewer. For future perspectives, more complete data can be obtained for quantitative and qualitative analyses by combining data from other databases (Web Of Sciences……)

# Declaration of competing interests

The author declares that he has no known competing financial interests or personal relationships that could appear to influence the work presented in this review

### *Appendix A. List of papers selected in the this analysis review*

| *No.* | *Document* | *Country/region* | *Research theme* |
|---|---|---|---|
| 1 | *Chao-Lung H. (2011 )* [37] | *Taiwan* | *Effect of rice husk ash on the strength and durability characteristics of concrete* |
| 2 | *Prustyj.K. (2016)* [29] | *India* | *Concrete using agro-waste as fine aggregate for sustainable built environment – A review* |
| 3 | *Singh M. (2017)* [30] | *India* | *An investigation on effect of partial replacement of cement by waste marble slurry* |
| 4 | *Güneyisi E. (2008)* [31] | *Turkey* | *Properties of self-compacting mortars with binary and ternary cementitious blends of fly ash and metakaolin* |
| 5 | *Vegas I. (2009)* [32] | *Spain* | *Freeze-thaw resistance of blended cements containing calcined paper sludge* |
| 6 | *Skaropoulou A. (2009a)* [33] | *Greece* | *Thaumasite form of sulfate attack in limestone cement mortars: A study on long term efficiency of mineral admixtures* |
| 7 | *Cheahc.B. (2017)* [34] | *Malaysia* | *The use of high calcium wood ash in the preparation of Ground Granulated Blast Furnace Slag and Pulverized Fly Ash geopolymers: A complete microstructural and mechanical characterization* |
| 8 | *Khederg.F. (2003)* [35] | *Iraq* | *Mathematical model for the prediction of cement compressive strength at the ages of 7 and 28 days within 24 hours* |
| 9 | *Skaropoulou A. (2009b)* [36] | *Greece* | *Long term behavior of Portland limestone cement mortars exposed to magnesium sulfate attack* |
| 10 | *Güneyisi E. (2009)* [38] | *Turkey* | *Effects of marble powder and slag on the properties of self compacting mortars* |
| 11 | *Cheah C.B. (2016)* [39] | *Malaysia* | *The engineering properties and microstructure development of cement mortar containing high volume of inter-grinded GGBS and PFA cured at ambient temperature* |
| 12 | *Majdih.S. (2020)* [40] | *Iraq* | *Experimental data on compressive strength and ultrasonic pulse velocity properties of sustainable mortar made with high content of GGBFS and CKD combinations* |
| 13 | *Bogasj.A. (2019)* [41] | *Portugal* | *Mechanical characterization of thermal activated low-carbon recycled cement mortars* |
| 14 | *Topçui.B. (2016)* [42] | *Turkey* | *Effect of high dosage lignosulphonate and naphthalene sulphonate based plasticizer usage on micro concrete properties* |
| 15 | *Rumšys D. (2017)* [43] | *Lithuania* | *Comparison of Material Properties of Lightweight Concrete with Recycled Polyethylene and Expanded Clay Aggregates* |
| 16 | *Huseieng.F. (2015)* [44] | *Malaysia* | *Synthesis and characterization of shelf-healing mortar with modified strength* |
| 17 | *Jeoni.K. (2020)* [45] | *South Korea* | *Investigation of sulfuric acid attack upon cement mortars containing silicon carbide powder* |
| 18 | *Lee T. (2020)* [46] | *South Korea* | *Setting time and compressive strength prediction model of concrete by nondestructive ultrasonic pulse velocity testing at early age* |
| 19 | *Nunes S. (2017)* [47] | *Portugal* | *Numerical optimization of self-compacting mortar mixture containing spent equilibrium catalyst from oil refinery* |
| 20 | *Mohammadhosseini H. (2020)* [48] | *Malaysia* | *Performance evaluation of novel prepacked aggregate concrete reinforced with waste polypropylene fibers at elevated temperatures* |
| 21 | *García-Verav.E. (2018)* [49] | *Spain* | *Influence of crystalline admixtures on the short-term behaviour of mortars exposed* |

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|---|---|---|---|
| | | | *to sulphuric acid* |
| 22 | *Sasanipour H. (2020)* [50] | *Iran* | *Durability assessment of concrete containing surface pretreated coarse recycled concrete aggregates* |
| 23 | *Kantarcı F. (2019)* [51] | *Turkey* | *Optimization of production parameters of geopolymer mortar and concrete: A comprehensive experimental study* |
| 24 | *Kimh.G. (2018)* [52] | *South Korea* | *Self-healing performance of GGBFS based cementitious mortar with granulated activators exposed to a seawater environment* |
| 25 | *Silva A. (2016)* [53] | *Portugal* | *Mechanical characteristics of lightweight mortars on small-scale samples* |
| 26 | *Güllü H. (2021)* [54] | *Turkey* | *The rheological, fresh and strength effects of cold-bonded geopolymer made with metakaolin and slag for grouting* |
| 27 | *Sherirm.A.A. (2018)* [55] | *Canada* | *Fresh state, mechanical & durability properties of strain hardening cementitious composite produced with locally available aggregates and high volume of fly ash* |
| 28 | *Benosmana.S. (2017)* [56] | *Algeria* | *Chemical, mechanical and thermal properties of mortar composites containing waste pet* |
| 29 | *Nogueirac.L. (2018)* [57] | *United States* | *Experimental analysis of cement-based materials under shear stress* |
| 30 | *Khajehnouri Y. (2019)* [58] | *Canada* | *Measuring electrical properties of mortar and concrete samples using the spectral induced polarization method: laboratory set-up* |
| 31 | *Borhant.M. (2020)* [59] | *Iraq* | *Experimental investigations on polymermodifiedperviousconcrete* |
| 32 | *Green B.H. (2008)* [60] | *United States* | *Development of a high-density cementitious rock-matching grout using nano-particles* |
| 33 | *Şahin F. (2021)*[61] | *Turkey* | *Effect of basalt fiber on metakaolin-based geopolymer mortars containing rilem, basalt and recycled waste concrete aggregates* |
| 34 | *Akyuncu V. (2021)* [62] | *Turkey* | *Investigation of physical and mechanical properties of mortars produced by polymer coated perlite aggregate* |
| 35 | *Polat R. (2018)* [63] | *Turkey* | *The influence of expanded perlite aggregate on compressive strength, linear autogenous shrinkage, restrained shrinkage, heat of hydration of cement-based materials* |
| 36 | *Lizarazo-Marriaga J. (2016)* [64] | *Colombia* | *Preliminary electrochemical cementation of high volume fly ash mortars* |
| 37 | *Ariffinn.F. (2015)* [65] | *Malaysia* | *Mechanical properties and self-healing mechanism of epoxy mortar* |
| 38 | *Uygunoğlu T. (2011)* [66] | *Turkey* | *Reuse of hydrated mortar as partial replacement material in cement* |
| 39 | *Nayel I.H. (2020)* [67] | *Iraq* | *Impact of elevated temperature on the mechanical properties of cement mortar reinforced with rope waste fibres* |
| 40 | *Othuman Mydin M.A. (2018)* [68] | *Malaysia* | *Coconut fiber strengthen high performance concrete: Young's modulus, ultrasonic pulse velocity and ductility properties* |
| 41 | *Mohdsama.R.M. (2015)* [69] | *Malaysia* | *Performance of epoxy resin as self-healing agent* |
| 42 | *Huseieng.F. (2021)* [70] | *Malaysia* | *Performance of epoxy resin polymer as self-healing cementitious materials agent in mortar* |
| 43 | *Hilal N. (2021)* [71] | *Iraq* | *Utilization of ceramic waste powder in cement mortar exposed to elevated temperature* |
| 44 | *Yap s.p. (2020)* [72] | *Malaysia* | *Relationship between microstructure and performance of polypropylene fibre reinforced cement composites subjected to elevated temperature* |
| 45 | *Chatterjee a. (2019)* [73] | *India* | *Bacterium amended 100% fly ash geopolymer* |
| 46 | *Patel g.k. (2016)* [74] | *India* | *Effect of natural organic materials as admixture on properties of concrete* |
| 47 | *Sahin f. (2021)* [75] | *Turkey* | *The effect of polyvinyl fibers on metakaolin-based geopolymer mortars with different aggregate filling* |
| 48 | *Thao a. (2020)* [76] | *United Kingdom* | *A preliminary characterisation of innovative semi-flexible composite pavement comprising geopolymer grout and reclaimed asphalt planings* |
| 49 | *Sadowski ł. (2020)* [77] | *Poland* | *The influence of texturing of the surface of concrete substrate on its adhesion to cement mortar overlay* |
| 50 | *Wong y.s. (2019)*[78] | *Malaysia* | *Performance of acid leached rice husk ash (ARHA) in Mortar* |
| 51 | *Sharan s. (2017)*[79] | *India* | *Investigations on the properties of coconut shell charcoal concrete* |
| 52 | *De silva s.d.c. (2016)*[80] | *Sri Lanka* | *Non-destructive evaluation of strength gain of ordinary portland cement mortar by ultrasonic pulse velocity method* |
| 53 | *Güllü, H. (2021)*[81] | *Turkey* | *The rheological, fresh and strength effects of cold-bonded geopolymer made with metakaolin and slag for grouting* |
| 54 | *Green b.h. (2012)*[82] | *United States* | *Development of a high-density, high-strength, cementitious grout using colloidal silica nano- particles* |
| 55 | *Nalon g.h. (2021)*[83] | *Brazil* | *Compressive strength, dynamic, and static modulus of cement-lime laying mortars obtained from samples of various geometries* |
| 56 | *Tomczak k. (2021)*[84] | *Poland* | *Key factors determining the self-healing ability of cement-based composites with mineral additives* |
| 57 | *Kocáb d. (2021)* | *Czech Republic* | *Ratio between dynamic Young's moduli of cementitious materials determined through different methods* |
| 58 | *Siddique s. (2021)*[85] | *South Korea* | *Characteristics of preplaced aggregate concrete fabricated with alkali-activated* |

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| | | | *slag/fly ash cements* |
| 59 | *Ekaputri j.j. (2016)*[86] | *Indonesia* | *An application of Rice husk ash (RHA) and calcium carbonate (CaCO3) as materal for self-healing cement* |
| 60 | *Kaya m. (2021)*[87] | *Turkey* | *Evaluation and multi-objective optimization of lightweight mortars parameters at elevated temperature via box–Behnken optimization approach* |
| 61 | *Adak d. (2021)*[88] | *India* | *Experimental studies on the development of a self-healing cementitious matrix for repair and retrofitting of concrete structures* |
| 62 | *Huang j.-m. (2021)*[89] | *Taiwan* | *Engineering properties of colorful mortar with inorganic color paste* |
| 63 | *Khan m.h. (2021)*[90] | *Pakistan* | *Properties of Mortars Formulated from Self-Compacting High-Performance Concrete Containing Various Mineral Additions* |
| 64 | *Boukhelkhal a. (2021)*[91] | *Algeria* | *Assessment of the Behavior Under Conventional and High Temperatures of Eco-friendly Self-Compacting Mortar Containing Glass and Ceramic Powders* |
| 65 | *Zhou b. (2021)*[92] | *China* | *Effect of all-component recycled gfrp on physical-mechanical properties and microstructures of concrete* |
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