Carbonation of Recycled Aggregates Concrete - Application of the ProKnow-C Methodology in the Selection of Bibliographic Portfolio, Systematic and Bibliometric Analysis

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***Abstract*— This paper presents an example of the application of the Knowledge Development Process-Constructivist (ProKnow-C) to the selection and analysis of a bibliographic portfolio. A brief explanation of the research topic is initially presented - concrete produced with the incorporation of recycled aggregates and the environmental importance of the reuse of residues in the construction industry. The necessity of employing a methodology to select and analyze bibliographic references is also discussed. The procedure of selection of the bibliographic portfolio is demonstrated step-by-step and the Research Lenses are presented. The final portfolio is shown in the results, as well as the systematic analysis, which identifies strengths and weaknesses of the portfolio and, therefore, allows the identification of research opportunities. The bibliometric analysis exposes the relevance of the papers selected for the portfolio.**

***Keywords*— ProKnow-C, Bibliometric Analysis and Systemic Analysis**

I. INTRODUCTION

The idea of sustainable development is based on the conscious use of natural resources to make it possible for future generations to have access to raw materials in the same way one has today. Therefore it is necessary to manage municipal solid waste in a way that maximizes the possibilities of reuse and recycling. An effective management of construction and demolition wastes (CDW) is essential for achieving a sustainable development (CAVALCANTI, 1994; JOHN, 2000; RYOU; LEE, 2014). Given these facts, the use of construction and demolition wastes as aggregates in concrete is essential for achieving this goal (HENDRIKS; NIJKERK; VAN KOPPEN, 2007; MEYER, 2009).

However, despite the evident benefits of the reuse of CDW, extensive research is still needed to understand the effects of its incorporation in structural concrete, particularly regarding durability aspects. This kind of waste has notoriously great variability - especially when no separation at source is carried out, as in the case of Brazil - and consists of several types of materials, with very different compositional characteristics (ANGULO, 2005; HENDRIKS; NIJKERK; VAN KOPPEN, 2007; NAGATAKI et al., 2004).

The incorporation of recycled aggregates affects several relevant parameters to the performance of concrete. The effects on mechanical resistance are the subject of numerous researches, and therefore more predictable (FERREIRA; BARRA; DE BRITO, 2011; GÓMEZ-SOBERÓN, 2002). However, durability aspects, – carbonation, chloride penetration, absorption, porosity – are less frequently addressed.

In the context of a research on the durability performance of recycled aggregates concrete (RAC), as in any other subject, there is a necessity to justify the study based on relevant scientific papers. This theoretical support makes it possible to identify research gaps that need to be filled or further investigated (AZEVEDO; ENSSLIN; JUNGLES, 2014; TASCA; ENSSLIN; ENSSLIN, 2013; VILELA, 2012).

In order to meet this demand, the ProKnow-C method, Knowledge Development Process – Constructivist, was developed (ENSSLIN, et al., 2010). Given the vast amount of papers available in electronic media, it is strictly necessary to apply a method that enables the portfolio selection and systematic revision (AZEVEDO; ENSSLIN; JUNGLES, 2014; ENSSLIN, 2010; ENSSLIN; ENSSLIN; PACHECO, 2012; TASCA; ENSSLIN; ENSSLIN, 2013).

Such method was developed by the Department of Production and Systems Engineering of the Federal University of Santa Catarina (UFSC), in the Lab of Multicriteria Methodology of Decision Support (LabMCDA) (WAICZYK; ENSSLIN, 2013). Among the main advantages of ProKnow-C it is worth highlighting the possibilities of: choosing papers by keywords; choosing the databases that best suit the research theme; selecting papers highly aligned to the research; identifying the most relevant studies for the portfolio composition (AZEVEDO; ENSSLIN; JUNGLES, 2014; ISATON, 2015; LACERDA; ENSSLIN; ENSSLIN, 2012).

The application of this type of research methodology allows to limit the search to recognized publications, and therefore, the researcher can save a great amount of time and easily justify his choices (ISATON, 2015; VILELA, 2012; WAICZYK; ENSSLIN, 2013).

The main objective of this paper is to present the results obtained by the application of ProKnow-C to the selection of a bibliographic portfolio and to the bibliometric and systematic analysis of it. In order to achieve this goal, the main topics of the research methodology adopted, as well as its partial and final results will be presented.

By demonstrating the use of the ProKnow-C method, this work contributes to researchers from several areas that demand the selection of a bibliographic portfolio and the performance of a bibliometric analysis. It is also possible that researchers in the field of CDW use in structural concrete could use the results of the systemic analysis presented here in order to explore new research possibilities.

II. PROCEDURES FOR THE SELECTION OF PAPERS

A. Research Framework

The work described in this paper can be classified as an Exploratory Survey. This kind of investigation aims to broaden, elucidate and change concepts and ideas in order to formulate more precise problems or searchable hypotheses for future researches (GIL, 2002).

According to Gil (2002), keeping the focus on the technical procedures adopted, this work can be classified as a Bibliographic Research. This type of research usually integrates a larger and more complete work. The bibliographic research expands the horizon of knowledge of the researcher, grounding the necessary knowledge bases.

In the case presented here, the instrument used to carry out the work is the ProKnow-C methodology.

B. Definition of Keywords and Databases to be Searched

The definition of the keywords occurred in two phases. Firstly, with the definition of the research topic, some initial papers, focused on the theme, were identified. The keywords in those papers were considered as possible research terms.

Subsequently, by meetings with experts and research groups, the search terms to be used were definitively determined. These keywords are shown in Table I. Two combinations of keywords to be searched can be obtained by crossing the columns.

TABLE I
KEYWORDS USED IN THE SURVEY

Keywords (1)	Keywords (2)
Recycled concrete Recycled aggregate	Carbonation

The following filters were used in the Capes periodicals portal to select the database to be used in the research: Knowledge Field: Engineering, Subcategory: Civil Engineering. Eighteen databases were found, of which eight provided complete and available papers. ScienceDirect database was chosen because the specialists involved in the work consider it as one of the most adequate to the research theme.

The temporal filter adopted corresponds to fifteen years, that is, there were considered papers published since 2001. Furthermore, only peer-reviewed journals were considered.

The search "Recycled aggregate and Carbonation" resulted in the total of 745 papers and the search for "Recycled concrete and Carbonation" resulted in 721 papers. Therefore, the raw portfolio consists of 1466 papers.

C. Filtering of Papers and Final Validation. Assembling Bibliographic Portfolio

The papers in the raw portfolio were imported to EndNote Basic Software, used for the references management (REUTERS, 2009). In the first step of the selection process using the software, it was possible to identify duplicate papers (which met both sets of keywords). Thereby, 537 duplicates were excluded, resulting in 929 remaining papers. The journals were organized in alphabetical order for a new search for duplicates by authors, since small spelling differences do not allow the correct identification of duplicate items by the software. In this stage, 166 duplicates were excluded, resulting in 763 papers lasting.

In the second selection stage, it was evaluated the alignment of the title of the papers to the proposed research theme. It was possible to identify 354 papers with titles fully aligned to the research objectives.

The third stage of selection consists of the evaluation of the scientific recognition of the papers. In order to measure that, the number of citations of each paper was considered, totaling 2806 citations. A representativeness of 85% was adopted, reaching then a sum of up to 2385 accumulated citations. The division of this number of citations by the total of papers results in six citations per paper. Thus, there were selected papers with more than six citations. This procedure resulted in the selection of 83 papers. Finally, in the final selection stage, reading and analysis of the selected papers abstracts resulted in a portfolio comprising 9 papers. Then, there was performed a review in the raw portfolio for recent sources, authored by researchers already selected in the final portfolio, that did not result in the selection of new papers.

III. RESULTS

A. Final Bibliographic Portfolio

The papers presented in Table II were selected for the final bibliographic portfolio:

TABLE II
BIBLIOGRAPHIC PORTFOLIO

No.	Papers selected for the bibliographic portfolio
1	LEVY, S. M.; HELENE, P. Durability of recycled aggregates concrete: A safe way to sustainable development. Cement and Concrete Research, v. 34, n. 11, p. 1975–1980, 2004.
2	EGUCHI, K. *et al*. Application of recycled coarse aggregate by mixture to concrete construction. Construction and Building Materials, v. 21, n. 7, p. 1542–1551, 2007.
3	ABBAS, A. et al. Durability of recycled aggregate concrete designed with equivalent mortar volume method. Cement and Concrete Composites, v. 31, n. 8, p. 555–563, 2009.
4	LIMBACHIYA, M. C. Coarse recycled aggregates for use in

new concrete. Proceedings of the Institution of Civil Engineers - Engineering Sustainability, v. 157, n. 2, p. 99–106, 2004.
5 RYOU, J. S.; LEE, Y. S. Characterization of Recycled Coarse Aggregate (RCA) via a Surface Coating Method. International Journal of Concrete Structures and Materials, v. 8, n. 2, p. 165–172, 2014.
6 ANGULO, S. C. et al. On the classification of mixed construction and demolition waste aggregate by porosity and its impact on the mechanical performance of concrete. Materials and Structures, v. 43, p. 519–528, 2009.
7 ZHU, Y. G. et al. Influence of silane-based water repellent on the durability properties of recycled aggregate concrete. Cement and Concrete Composites, v. 35, n. 1, p. 32–38, 2013.
8 GOMES, M.; BRITO, J.; BRAVO, M. Structural concrete with incorporation of coarse recycled concrete and ceramic aggregates: durability performance. Materials and Structures, v. 42, n. 5, p. 663–675, 2009.
9 EVANGELISTA, L.; DE BRITO, J. Durability performance of concrete made with fine recycled concrete aggregates. Cement and Concrete Composites, v. 32, n. 1, p. 9–14, 2010.

B. *Bibliometric Analysis*

After the selection of the papers, the relevance and scientific recognition of the journals in which they were published were evaluated. In order to do so, the journals were surveyed in CAPES Qualis system and a comparison was made regarding the number of times each selected paper was cited.

The classification of journals in CAPES Qualis system is done in an alphanumeric way, with "A1" being the highest ranking and "C" the lowest ranking. The classification considered here refers to the area "Engineering 1". The term "Not applicable (NA)" was used for those unclassified journals. Fig. 1 indicates the ranking of journals that make up the portfolio.

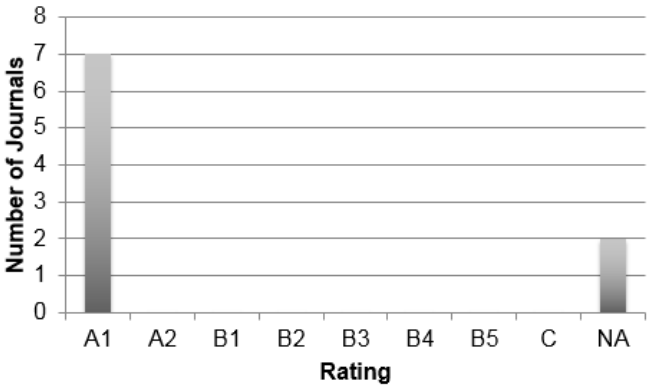

Fig. 1. Classification of the journals according to CAPES Qualis system

It can be noticed that the majority of the periodicals fits the maximum rate in CAPES evaluation system, and this fact is a sign of the quality of the portfolio. Only two journals do not fit the adopted classification system.

Fig. 2 indicates the number of citations for each of the papers constituting the portfolio. It can be noticed that most of the papers reached values near or greater than 50 citations, thus the scientific relevance of the portfolio is demonstrated.

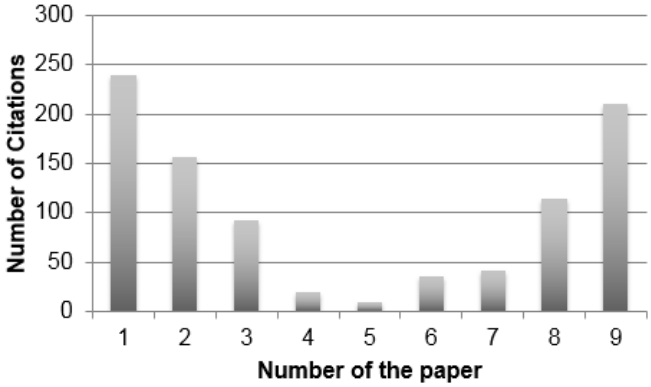

Fig. 1. Number of citations of each paper on Google Scholar

C. *Definition of Research Lenses and Systematic Analysis*

The research lenses can be defined as key points to be analyzed in each one of the papers in the final portfolio. Through these lenses it is possible to evaluate the strengths and weaknesses of each work, thus emphasizing research opportunities.

The research lenses employed addressed five key points. These were analyzed in each one of the papers that compose the final portfolio. The lenses adopted are presented and briefly explained below:

Does the research address durability related aspects of recycled concretes? According to Gómez-Soberón (2002), the study of long-term effects of the addition of CDW to the concrete is of substantial relevance, since these properties are highly influenced by the materials used.

1. Is it employed any CDW treatment method? In order to evaluate the effects of the addition of CDW to the concrete, it is essential to know if the residue has undergone some type of treatment in order to increase its quality, since treatment methods alter the characteristics of the CDW.
2. Was the CDW obtained in the field or from a recycling plant? Laboratory produced CDW have different characteristics from those obtained in the field (HENDRIKS; NIJKERK; VAN KOPPEN, 2007).
3. Is any CDW segregation method used? According to Angulo (2005), residues in Brazil, in most cases, consist of a mix, mainly of natural and ceramic aggregates. As they have very different characteristics, the separation of these fractions has a direct influence on the quality of the final concrete.
4. Were the specimens molded using red and gray residues? This lens is directly connected to the previous one, since the typical segregation of the residues leads to the division between ceramic (red) and cementitious (gray) CDW. In the case of non-segregation, the use of mixed waste also influences the final quality of concrete.

The Table III was formulated after reading the selected papers and presents the result of the systemic analysis of the bibliographic portfolio. The results indicate the responses to

each of the presented lenses. Based on these answers it is possible to identify some research possibilities.

TABLE III
SYSTEMATIC ANALYSIS OF THE BIBLIOGRAPHIC PORTFOLIO

Articles	Research Lenses				
	1	2	3	4	5
1	Yes	No	No	No	Yes
2	Yes	No	No	No	No
3	Yes	No	Yes	No	No
4	Yes	No	Yes	No	Yes
5	Yes	Yes	No	No	No
6	No	No	Yes	Yes	Yes
7	Yes	Yes	Yes	No	Yes
8	Yes	No	No	No	Yes
9	Yes	No	No	No	No

The results of Lens 1 analysis were expected. The keywords used for building the bibliographic portfolio presupposed the approach of aspects related to the durability of recycled concretes.

Paper 1 indicates a reduction of durability-related aspects in concrete with the substitution of the natural aggregate by CDW, and this reduction is proportional to the substitution content (LEVY; HELENE, 2004).

Paper 2 shows that durability characteristics did not demonstrate significant variations compared to the concrete with natural aggregate, except for some specimens in which the CDW used was obtained from demolition blocks (EGUCHI et al., 2007).

Paper 3 demonstrates that durability related aspects were also negatively affected by the addition of CDW. Moreover, the dosage method used in the paper (Equivalent Mortar Volume Method) also contributed to the worsening of the concrete's performance in this matter, since the amount of cement in the trace is lower than in the conventional dosage (ABBAS et al., 2009).

Paper 4 states that with adjustments in a defined and previously tested trace, it is possible to achieve satisfactory durability results. Results demonstrate that carbonation, abrasion, and ice-thaw cycles resistances are very similar in traces with and without CDW (LIMBACHIYA, 2004).

Paper 5 indicates that it is possible to perform a CDW treatment in order to improve its characteristics. In the case of durability, the performance of the treated CDW was intermediate. In other words, the durability performance of the treated CDW was between the untreated one and the natural aggregates (RYOU; LEE, 2014). Paper 6 does not perform a durability study.

Paper 7 reports that the durability aspects evaluated were influenced by the silane treatment presented. The treated CDW performed better than the untreated ones (ZHU et al., 2013).

The results reported in Paper 8 show that the durability performance of concrete made from recycled aggregates is worse than those made with natural aggregates. However, this difference is small, with a maximum of 20% (GOMES; BRITO; BRAVO, 2009).

Paper 9 indicates that the durability of the concrete is inversely proportional to the content of recycled aggregates in the mixture. Both the carbonation resistance and the resistance to the penetration of chloride ions decreased with the addition of CDW (EVANGELISTA; DE BRITO, 2010).

Research Lens 2 led to the identification of a possible research niche to be developed. Only Papers 5 and 7 present CDW treatments performed in order to improve their characteristics. Paper 5 presents a treatment by means of polycarboxylate, whereas Paper 7 presents results of a treatment that employs silane (RYOU; LEE, 2014; ZHU et al., 2013).

Both treatments increase the mechanical and durability performance of recycled concretes compared to concretes fabricated with untreated CDW. (RYOU; LEE, 2014; ZHU et al., 2013)

Research Lens 3 presents more diverse results. It concerns the origin of the CDW. Through the selected papers, it is not possible to draw conclusions about the influence of the CDW origin on the characteristics of the final recycled concrete, and this theme can be seen as a research opportunity.

Research Lens 4 identifies another research possibility. Only Paper 6 presented a method for CDW segregation. This type of approach is very important in the Brazilian context, since the national recycled aggregate usually has several materials with different characteristics in its constitution (ANGULO et al., 2009; JOHN, 2000).

The results of Research Lenses 4 and 5 are strongly connected. Since it is preferred not to work with ceramic (red) materials, the materials segregation is not needed.

After the systematic analysis it is possible to identify some potential research opportunities:

- Effects of the addition of segregated CDW on the durability parameters of recycled concretes;
- Effects of the CDW origin on the final characteristics of recycled structural concretes;
- Differences between the various segregated CDW classes and how those differences affect the final characteristics of recycled concretes;
- Use of segregated and treated CDW in recycled concretes;
- Comparative study between the characteristics of residues obtained in the field/plant and those produced in the laboratory, both after treatment.

IV. CONCLUSION

The research methodology applied in this study (ProKnow-C) reached the aim of selecting and analyzing a consistent bibliographic portfolio. It was possible to proceed both a systematic and bibliometric analysis.

Through the systematic analysis it was possible to identify

research gaps to be filled and through bibliometric analysis, the relevance of the papers to the bibliographic portfolio was evidenced.

The objectives of the paper have been achieved. It has been proven that ProKnow-C is a viable method for researchers to build bibliographic portfolios with relevant scientific papers.

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