Bibliometric analysis of Web of Science–indexed papers on concrete segmental bridges

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- This paper provides a bibliometric analysis of 242 references covering the years 1900 through 2013 from the Web of Science.
- The analysis compares data such as author information, journal and year of publication, WoS category, and funding agency.
- This study reveals that the main sources of concrete segmental bridge references are United States journals related to concrete structures and that more than half of the selected references have been written by authors in the United States.

Segmental fabrication methods are commonly used in a variety of fields. The term *segmental fabrication* refers to any procedure in which segments are assembled to create a larger element. A concrete segmental bridge is a bridge in which concrete segments, whether cast-in-place or precast, are assembled to form the superstructure of the bridge.[1] Several technologies and construction methods can be used, such as the span-by-span method, the free cantilever method, and the incremental launching method.

Concrete segmental bridges originated in Europe as a result of the need to reconstruct bombed-out bridges and build new bridges after World War II.[2] The large number of bridges spurred the development of a variety of construction methods in a short time.[1] Under these circumstances, prestressed concrete showed its versatility and economy, allowing bridge construction in a quick and efficient manner.

The first precast concrete segmental bridge, the Luzancy Bridge across the Marne River in France, was designed and built by Eugene Freyssinet in 1946.[1] The first prestressed concrete segmental bridge in the United States was a small bridge in Madison County, Tenn., built in 1950.[3] Otherwise, concrete segmental bridge technology was practically disregarded in the United States until the

technological advancements of the 1970s. Once its suitability for major or long-span bridges was proved, concrete segmental bridge technology reemerged as a strong competitor of established materials and conventional bridge construction methods.[1]

The most important factors contributing to the expansion of concrete segmental bridges arise from speed of construction, quality control of factory production, reduction of on-site labor and operations, reduced use of materials, lower life-cycle costs, longer design life, appealing aesthetics, minimal traffic disruption during construction, and adaptability to curved road alignment.[4,5] All of these factors are included in the five major ingredients in the success of a long-span bridge[6] where the use of concrete segmental bridge technology further enhances its benefits: sound structural design, efficient construction, durability, aesthetics, and economics. The success of concrete segmental bridges is reflected in the number of bridges and the awards they have received from PCI and the American Society of Civil Engineers.[5]

In addition, research is always required to create new technology and to improve design and construction practices and processes. This, in turn, requires the support of industry. Industry plays a key role in identifying areas where research is needed and encouraging its application. At the same time it enhances the creativity of those who work on construction projects.[7,8] Concrete segmental bridges are an example of this last aspect. At the same time concrete segmental bridges were further developed and becoming more popular, several papers on this topic appeared in international scientific journals. The first paper on concrete segmental bridges indexed in the Web of Science (WoS) was published in 1968, and the number of published papers dealing with concrete segmental bridges through 2013 is observed from a bibliometric approach.

The term *bibliometric* was first used by Pritchar,[9] who initially described it as the "application of mathematics and statistical methods to books and other media of communication" and later as the "metrology of the information transfer process" aiming at the "analysis and control of the process."[10] Bibliometric methods measure scientific progress by identifying patterns and global trends, revealing dynamics in scientific publications in a certain research area or discipline using quantitative and visual processes.[9,11] However, bibliometric analyses related to civil engineering are scarce and are not directly focused on concrete. Some recent studies have analyzed the research activity in the context of a category from WoS, such as Engineering, Civil[12] or Construction and Building Technology,[11] in the context of a country[13,14] or in the context of a specific journal;[15] Construction Research is also analyzed as a topic.[8] The oldest of these dates from 2004; all of them have aimed at producing an overall picture of the evolution of research activity, simultaneously revealing trends from different perspectives, such as authors, research organizations, countries, journals, dates, research categories, keywords, citations, impact factors, and other indicators.

The purpose of this paper is to present the findings of a bibliometric analysis based on indexed scientific papers that focus on concrete segmental bridges as a main topic. To this end, the WoS was considered the best source to reflect the scientific and technical activity related to this bibliometric study. A selection of 242 references was compiled from the Science Citation Index Expanded database covering 1900 through 2013. This paper is not a state-of-the-art report on concrete segmental bridges, but it offers an overview and an extensive list of references from the perspective of their main topical content as a way of improving the potential use of this pioneer bibliometric analysis carried out in the field of concrete segmental bridge technology.

The section "Materials and Methodology" describes step-by-step materials and methods used to obtain the selected database after a conscientious search strategy by combining several search fields and refinement actions. The section "Results and Discussion" includes the analysis of results through a wide variety of comparatives of data directly obtained from WoS as well as data processed by the authors. Concluding remarks are detailed in the last section, followed by the list of references cited in this paper. In addition, Appendix A includes the 242 references, in alphabetical order with an additional record number, which provides readers with more synthesized information regarding the proposed classification based on the main topical content and citations ranking.

Materials and methodology

To obtain extensive and rigorous information regarding the scientific and technical activities related to concrete segmental bridges, the WoS emerged as the best representative repository for this bibliometric study. WoS, which can be accessed through http://apps.webofknowledge.com, is widely used by researchers and analysts in industry and academia and is recognized as the most comprehensive and versatile research platform available for academic researchers, information professionals, and research and development professionals. At the same time, it provides a single destination to access the most reliable, integrated, multidisciplinary research.[16]

Given the idiosyncrasy of the topic of concrete segmental bridges, the selected database was the Science Citation Index Expanded (SCI-EXPANDED), which is one of the nine indexes included in the Web of Science Core Collection and covers more than 8500 major journals across 150 disciplines from 1900 to the present. The time span considered in this study ranges from 1900 through 2013 because most of the records are updated in WoS with some

delay with respect to the date of publication. In this way, as the information was extracted from WoS on April 17, 2014, and checked again on May 9, 2014, it guarantees that all records for 2013 had been updated, allowing a complete analysis through the end of that year.

The following subsections detail the search strategy used, the refinement actions applied, and the information extraction processes.

Search strategy

Several preliminary explorations of available data were made in February and March 2014 to find various and complementary options. Then a carefully selected and extensive database was compiled through a search strategy that simultaneously combined six basic search fields by using the logical operator "OR" within the same search operation, as follows:

- In the title field: segmental* (bridge OR girder OR beam)
- As a topic field: concrete segmental* (bridge OR girder OR beam OR viaduct)
- As a topic field: cable-stayed segmental bridge
- As a topic field: splicing erection
- As a topic field: "spliced girder" OR "spliced I girder" OR "spliced U girder" OR "spliced bulb tee"
- As a topic field: "segmental bridge"

As a result, 300 records initially appeared regardless of the document and research area (WoS categories), which required the application of some refinement actions.

Refinement actions

To obtain the most representative contributions, a refinement based on the document type was applied. Ten out of thirty-eight possible document types considered in WoS were present, and only two of them were selected: papers-articles (266 records) and reviews (4 records), for a total of 270 records.

A second refinement was based on WoS categories in two steps, as follows:

- 248 records resulted after the following WoS categories were selected:
  - Computer Science Interdisciplinary Applications
  - Construction Building Technology
  - Education Scientific Disciplines
  - Engineering Civil
  - Engineering Mechanical
  - Engineering Multidisciplinary
  - Mathematics Interdisciplinary Applications
  - Materials Science Characterization Testing
  - Materials Science Composites
  - Materials Science Multidisciplinary
  - Mechanics
  - Transportation
  - Transportation Science Technology
- 2 records were discarded by excluding the following WoS categories:
  - Engineering Biomedical
  - Geosciences Multidisciplinary
  - Mathematical Computational Biology
  - Medical Informatics

A final refinement action on the remaining 246 records was made based on the document content from the corresponding title and abstract. Only 4 records (record numbers 87, 90, 97, and 188 when ordered according to publication date—oldest to newest) were discarded because they were not directly related to concrete segmental bridges. In this way, as a starting point before extracting and analyzing the information, the compiled database from WoS included 242 records, the first of which was published in 1968.

Extracting information

Once the database had been obtained, all records were added to a marked list within WoS to extract the following information:

- Author(s)/Editor(s)
- Title
- Source (Source Title, Volume, Issue, Pages, and Publication Data)
- Abstract

- Keywords (Author Keywords and KeyWords Plus)
- Document Type
- Language
- Times Cited
- Cited Reference Count
- Author Identifiers
- Addresses
- Publisher Information
- Funding Information
- Web of Science Categories
- Research Areas

The extracted information was then saved in tab-delimited (Win) format and was also exported to EndNote online, a bibliography manager available as a complementary tool within the WoS platform.

Other groups of information were obtained using other options offered in WoS:

- The "analyze results" option allows ranking the records by fields according to the record count or the selected field. The following ranks were obtained: authors, countries, funding agencies, organizations-enhanced (for preferred organization names and/or their name variants), publication years, source titles, and Web of Science categories.

- The "create citation report" option gives, for each record, the number of citations (total and by year) and the average citations per year, as well as a global report including the total number of times cited, citing papers, and average citations per item for all records on the marked list.

The data included in all three groups of information were processed through spreadsheet applications to manage, analyze, and compare the results as preliminary steps for later treatment, interpretation, and discussion.

Both "times cited" and "create citation report" report results from the updated records in WoS at the consultation time (April 17, 2014, for this study).

Regarding keywords, the uppercase and lowercase versions, singular and plural terms, and the presence of hyphens separating words in compound keywords were considered in the corresponding count, which included both related items such as author keywords (listed by the author or publisher) and KeyWords Plus (proposed by Thomson Reuters' editorial experts in science). For example, "box-girder," "box girders," and "Box-girder" were considered together and identified as the single term "box(-)girder(s)."

Results and discussion

After the data were extracted and processed, a wide variety of analyses and comparatives through the bibliometric study were conducted, some of them using data directly obtained from WoS as well as data processed by the authors. For comparison and to contextualize some analyses, additional data were gathered from WoS, such as the number of publications on concrete bridges by the most representative authors in the concrete segmental bridges field, and global data regarding a search based on "concrete bridge" were also obtained by following the same refinement actions and extracting-processing steps described above. The same time spans were considered for both databases (concrete segmental bridge and concrete bridge): records from 1900 through 2013 and citations report gathered on April 17, 2014. The concrete bridge database consisted of 4922 records (initially 5621, 5420 after the first refinement [5356 papers and 64 reviews], 4965 after step 1 of the second refinement, and 4922 after step 2 of the second refinement; no final refinement action based on content was made), 4899 of them from 1968, which implies that the 242 records on concrete segmental bridges represent 4.9% of all records on concrete bridges.

In the following subsections, the term *paper* refers to both document types selected from WoS (papers and reviews). The following subsections include the 10 subjects that have been analyzed: years, journals, countries, authors, organizations, funding agencies, WoS category, keywords, topics, and citations. In general terms, except for analysis based on dates, figures commonly show information arranged by ranking count and in alphabetical order within the same count value.

Regarding the publication language, it is worth remarking that, out of the 242 papers analyzed, only 1 was written in Spanish, 4 in German, and the remaining 237 (98%) in English.

Years

This section describes the evolution of the number of published papers over time. A general increasing trend in the number of papers from 1968 (year of first paper, despite the first concrete segmental bridge having been built in 1946) through 2013 is observed, though several ups and downs are also observed (**Fig. 1**). Only 3 out of 46 years had no papers published in them, 9 years had 10 or more papers (none before 2000), and a maximum of 17 papers appeared in 2013.

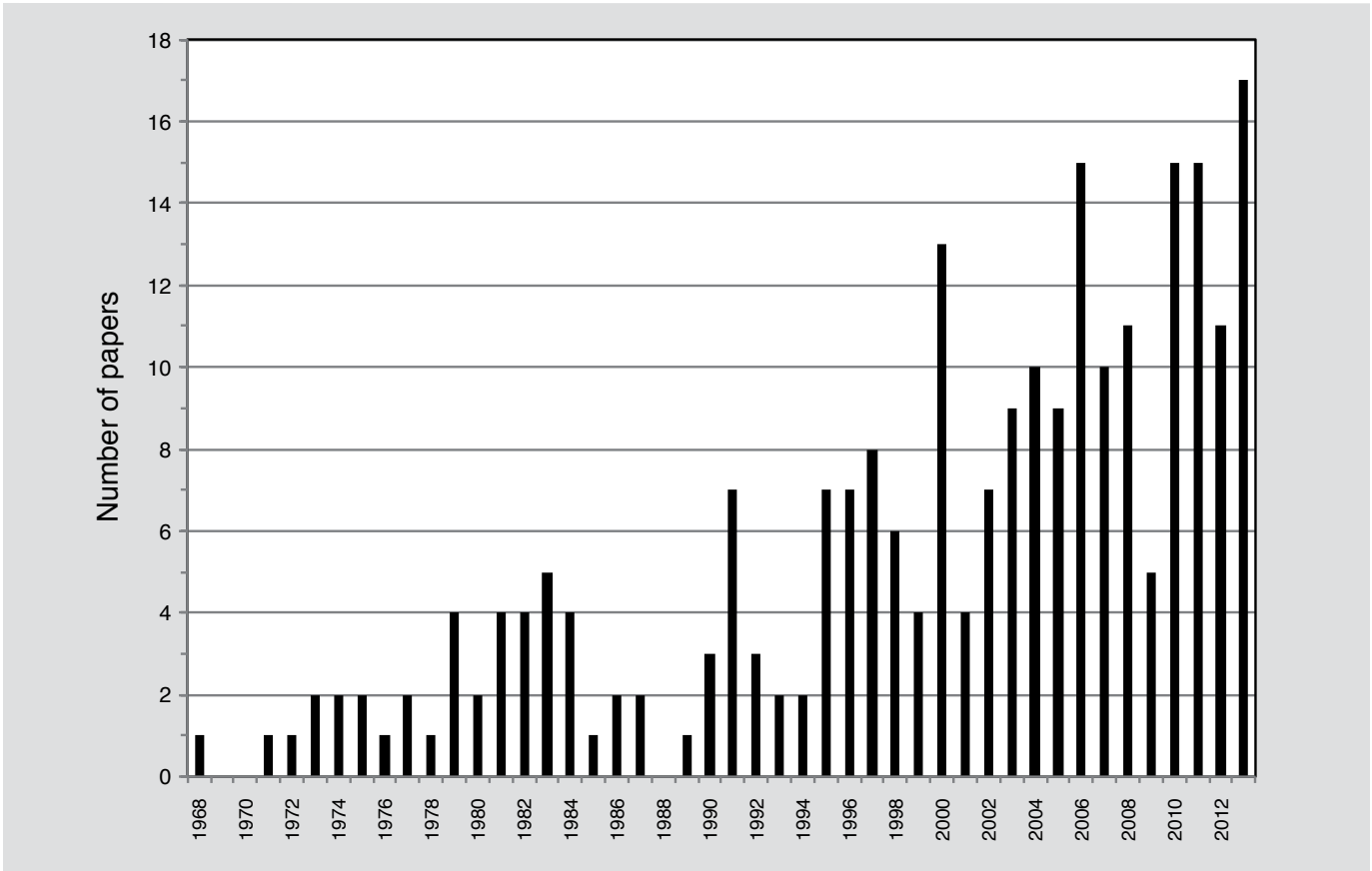

Figure 1. Evolution of number of concrete segmental bridge papers published.

Regarding the number of papers on concrete segmental bridges compared with the total number of published papers on concrete bridges, **Fig. 2** shows that from 1973 through 1984, the percentage of papers on concrete segmental bridges as a proportion of all papers on concrete bridges exceeded 30% in several years, with a maximum of 67% in 1981. An increased relative presence of concrete segmental bridge papers can be seen through 1981, indicating that during this time, concrete segmental bridge technology was strongly emerging and many papers on concrete bridges specifically focused on concrete segmental bridges. After 1981, the relative presence of papers on concrete segmental bridges decreases, despite the general increasing trend followed by the number of papers in Fig. 1. This can be attributed to the growth of research activities focusing on other aspects of concrete bridges rather than on concrete segmental bridges.

Journals

This analysis identifies the main journals that have published papers on concrete segmental bridges. **Figure 3** shows the number of papers ordered according to the journal rank. *PCI Journal* and its predecessor, *Journal of the Prestressed Concrete Institute*, account for 30.6% of all concrete segmental bridge papers.

A total of 45 journals have published papers on concrete segmental bridges: 20 journals published only 1 paper each, 8 journals 2 papers each, 12 journals published 3 to 9 papers each, and 5 journals published more than 10 papers each. Focusing on the 5 journals with 10 or more papers, 4 correspond to publishers in the United States (*PCI Journal*/*Journal of the Prestressed Concrete Institute*, *Journal of Bridge Engineering*, *ACI Structural Journal*, and *Transportation Research Record*) and 1 in the United Kingdom (*Engineering Structures*). These 5 journals include a total of 145 papers on concrete segmental bridges, or 60% of the papers considered in this study.

Countries

The analysis establishes the ranking of the countries leading in concrete segmental bridge technology based on the number of papers published. Thirty-two countries are identified. The United States leads this ranking with 135 papers (56% of papers considered in this study), far ahead of other countries (**Fig. 4**). Only three countries other than the United States have more than 10 papers: Spain (19), Taiwan (13), and South Korea (11). Sixteen countries have only 1 paper each, and the remaining twelve countries have from 2 to 8 papers.

Bars in **Fig. 5** represent the number of papers by authors in the United States through the years, whereas a rhombus represents papers by authors in countries other than the

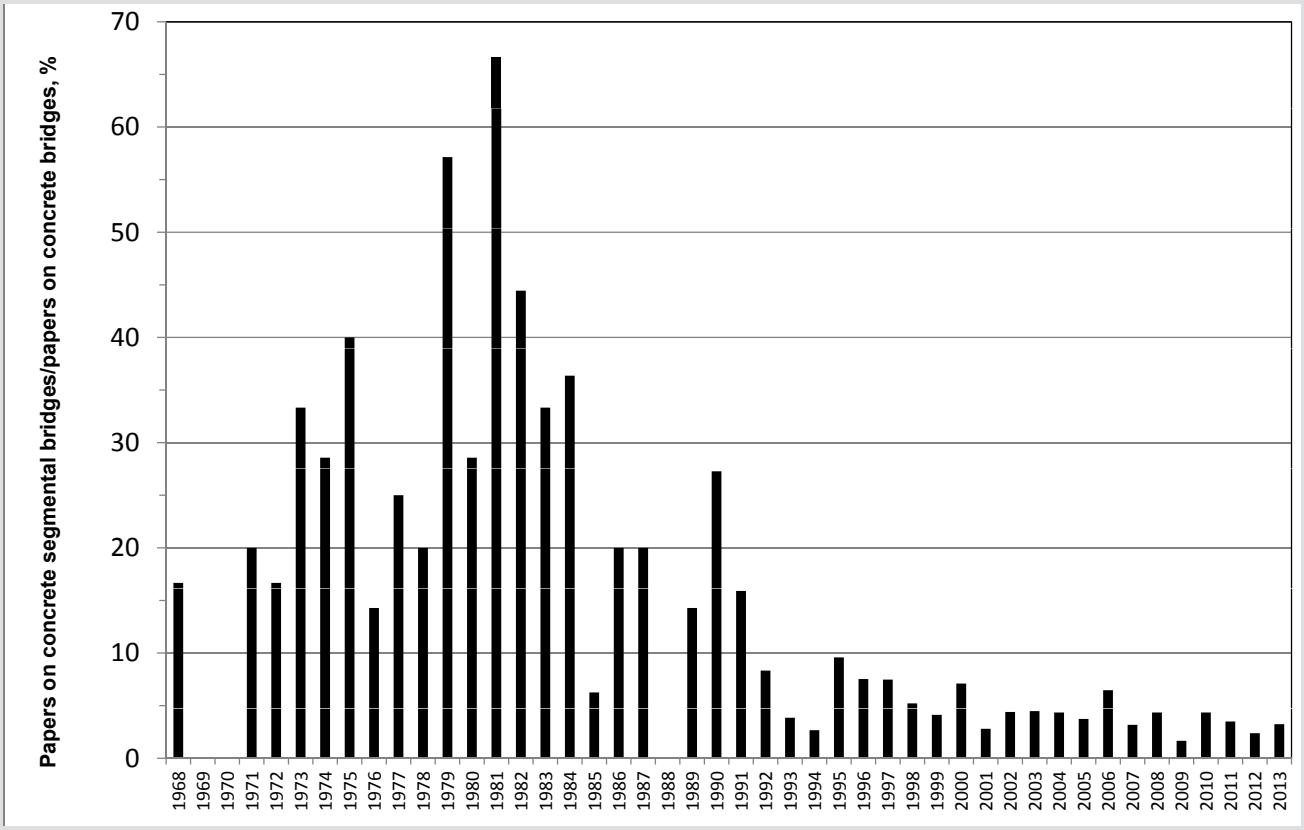

Figure 2. Relative presence of papers on concrete segmental bridges to total papers on concrete bridges.

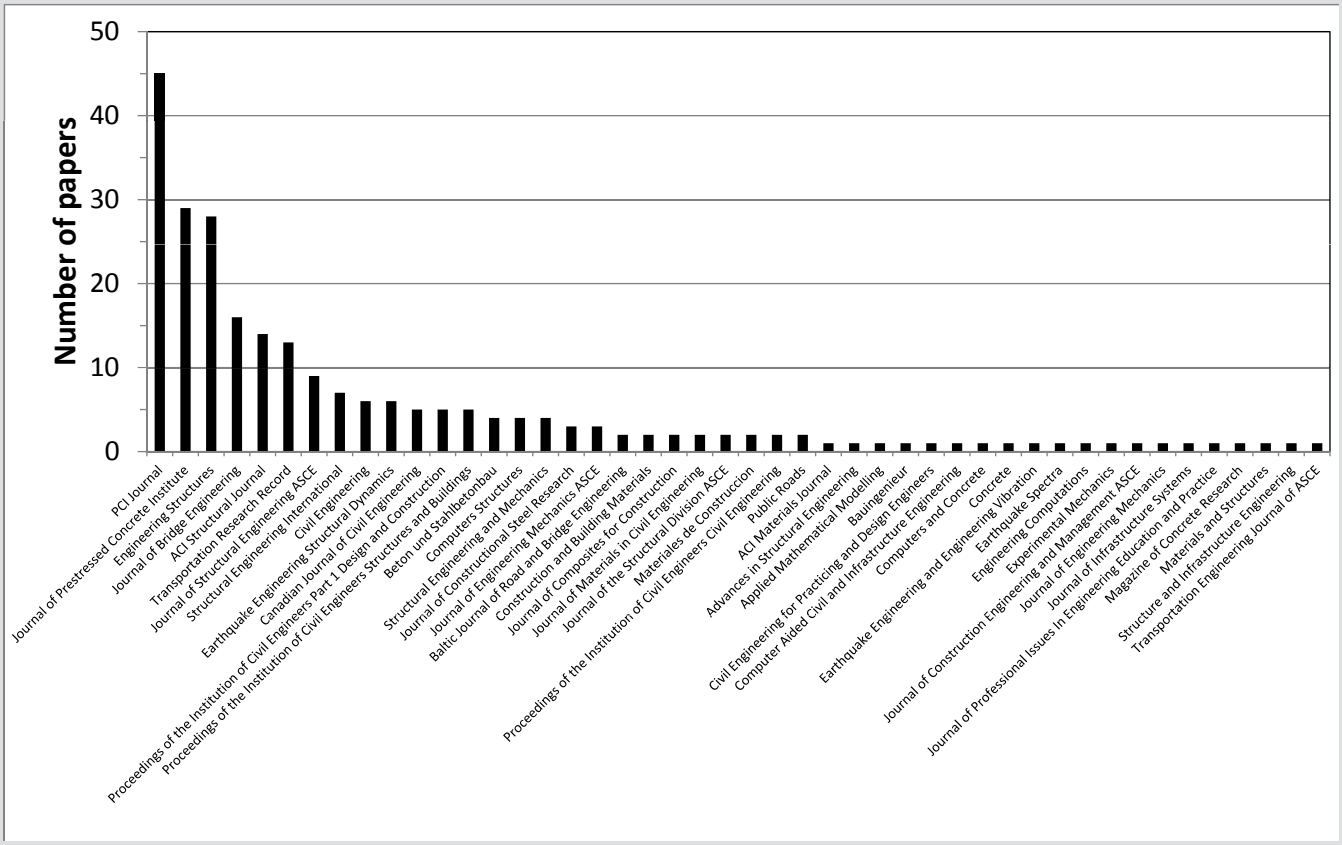

Figure 3. Ranking of journals based on number of papers on concrete segmental bridges.

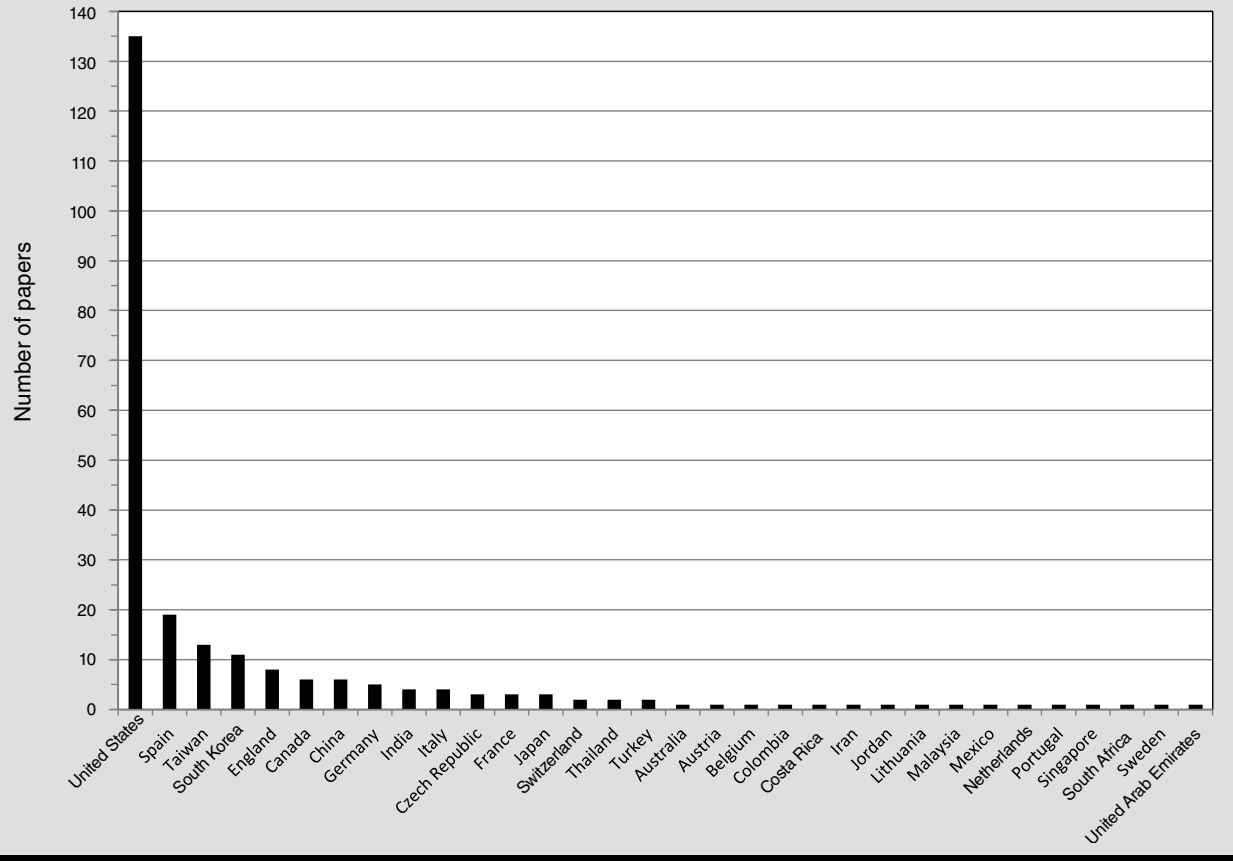

Figure 4. Ranking of countries based on number of papers on concrete segmental bridges.

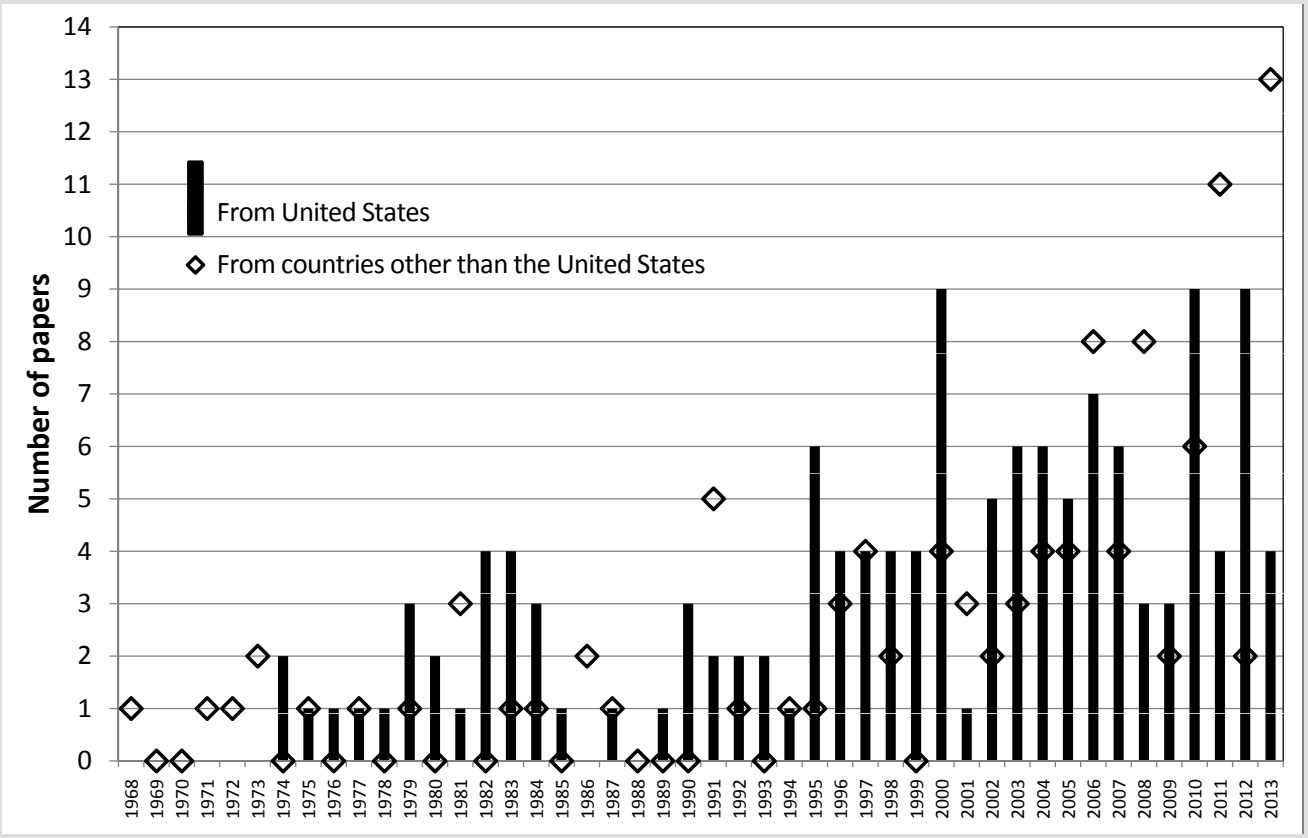

Figure 5. Number of papers on concrete segmental bridges from the United States and all other countries.

United States. As observed, the first paper by an author in the United States was published in 1974. Since then, in only 2 years (1986 and 1988) were there no papers published by authors in the United States, whereas there were 11 years with no papers published by authors in any of the other countries. From 1974 to 2013, the United States had more papers than all other countries combined in 26 years, an equal number in 5, and fewer in 8. (There were no papers published on concrete segmental bridges in 1988.) As a result, the evolution of scientific production in the United States seems more regular, whereas in other countries it experiences more exaggerated ups and downs.

In the context of all concrete bridges, the following (papers on concrete segmental bridges/papers on concrete bridges) ratios have been obtained for the top 10 countries, which have 4 or more papers on concrete segmental bridges each: United States, 6.3%; Spain, 16.1%; Taiwan, 12.1%; South Korea, 3.7%; United Kingdom, 3.7%; Canada, 1.4%; China, 1.4%; Germany, 2.5%; India, 5.6%; and Italy, 2.0%. The average percentage of concrete segmental bridge contributions within the concrete bridge database is 4.9% (242 of 4922). As observed, the extraordinary contribution of the United States to the field of concrete segmental bridges represents 6.3% of its total number of papers on concrete bridges, whereas Spain (16.1%) and Taiwan (12.1%) have a strong presence that implies greater specialization. Spain is the country with the second highest number of contributions (Fig. 4), and its 16.1% ratio is more than triple the average percentage.

Authors

Four hundred thirty-seven different authors have been identified from 599 records of authors contributing to papers on concrete segmental bridges, and 5 of 242 papers appear as anonymous. Except for the anonymous papers, the average number of authors per paper is 2.5 (599 records of authors over 237 papers). **Table 1** presents the top 20 contributing authors representing 20.7% of papers (124 of 599 records of authors), all of whom have 4 or more papers each and are first authors of 20.2% of papers (49 of 242 papers). For comparison purposes, the number of papers on concrete bridges and the percentage of papers on concrete segmental bridges in relation to all papers on concrete bridges are included in Table 1.

Organizations

Regarding the affiliations of the authors appearing in the concrete segmental bridge database, 232 different organizations from academia, government, and industry have been identified from a total of 376 records of organizations. **Table 2** lists the top 27 contributing organizations, which cover 38.6% of papers (145 of 376), all of them having 3 or more papers each. The top 10 positions (having 5 or more records each) cover 22.9% of papers, and the top 4 (having 9 or more records) represent 13.0% of the 376 records of organizations. Six of the 10 first positions (having 5 or more records), and 2 of the 4 first positions (having 9 or more records), correspond to U.S. organizations. Two organizations from Spain appear among the top 10, one of them in the first position. The other two organizations within the top 10 are from Taiwan. Only one nonacademic organization is in the top 10: FIGG Engineering Group, which ranks fifth.

Funding agencies

This analysis identifies the main funding agencies supporting research projects related to concrete segmental bridges. A total of 72 projects were funded by 47 different agencies, 11 of which have funded more than 1 project. These 11 main agencies are the U.S. Department of Transportation (which includes the Federal Highway Administration), which funded 7 projects; the National Science Foundation, which funded 5 projects; the California Department of Transportation, National Center for Research on Earthquake Engineering, Transportation Northwest Transnow, the Spanish Junta de Comunidades de Castilla-La Mancha, the Spanish Ministry of Science and Technology, and the Texas Department of Transportation, which funded 3 projects each; Hanyang University in South Korea, the Spanish Ministry of Education, and the Taiwan Area National Expressway Engineering Bureau, which funded 2 projects each. Five of these 11 main agencies are from the United States, three from Spain, two from Taiwan, and one from South Korea.

WoS category

Each paper is classified within one or more category in agreement with WoS categories associated with the corresponding journals in which they are published. In this analysis, the objective is to obtain a distribution map of the concrete segmental bridge database based on scientific categories as defined in WoS. To put the results in context, additional data from the concrete bridge database for the same 15 WoS categories identified within the concrete segmental bridge database have been used (only 4.5% of data from concrete bridges are out of these 15 WoS categories). Three hundred eighty-eight records of WoS category have been counted for the case of concrete segmental bridge, resulting in an average of 1.6 categories per paper (388 records of WoS category over 242 papers), whereas 9311 records for the case of concrete bridge with 1.9 (9311 records of WoS category over 4922 papers) as average.

Table 3 presents the distribution of records and ratios of (number of records within a category) versus (total papers within database [242 or 4922]) per WoS categories for both concrete segmental bridge and concrete bridge databases. These ratios are representative of the relative presence of each category in the database, and not the weight of each

Table 1. Main contributing authors

Author name	Number of papers	Cases as first author	Number of papers on concrete bridges	Percentage of papers, concrete segmental bridge/concrete bridge
Breen, J. E.	15	4	17	88.2
Aparicio, A. C.	11	1	22	50.0
Ramos, G.	10	2	13	76.9
Turmo, J.	7	7	9	77.8
Bažant, Z. P.	6	5	18	33.3
Casas, J. R.	6	2	24	25.0
Chou, C. C.	6	6	6	100.0
Ou, Y. C.	6	4	7	85.7
Seible, F.	6	1	37	16.2
Chang, K. C.	5	0	11	45.5
Kreger, M. E.	5	0	13	38.5
Megally, S.	5	4	7	71.4
Restrepo, J. I.	5	0	10	50.0
Shushkewich, K. W.	5	5	8	62.5
Tadros, M. K.	5	1	39	12.8
Yu, Q.	5	1	5	100.0
Freyermuth, C. L.	4	4	5	80.0
Ghali, A.	4	2	11	36.4
Lee, G. C.	4	0	7	57.1
Veletzos, M. J.	4	0	4	100.0

category over all categories. Therefore, the total exceeds 100%.

Most papers are associated with three main WoS categories: Engineering Civil, Construction Building Technology, and Materials Science Multidisciplinary (Table 3). With the different scale of percentages in mind, distributions for both concrete segmental bridge and concrete bridge databases appear similar in general terms. Within the three main WoS categories, only one significant difference has been found: Construction and Building Technology is more present in concrete segmental bridge than in concrete bridge, while the opposite is true of Materials Science Multidisciplinary. That is, technological aspects are more present in the concrete segmental bridge database rather than research on materials. Other minor differences do not prove significant because of the lesser number of records.

WoS also provides a classification of papers based on research areas (one or more per paper). Three hundred sixty-five records of research areas are computed in this case and are distributed as follows: Engineering, 161 records; Construction Building Technology, 139; Materials Science, 35; Transportation, 15; Computer Science, 7; Mechanics, 5; Mathematics, 2; and Education Educational Research, 1.

There is a considerable parallelism between the results from both categories and area classifications.

Keywords

This analysis intends to reveal the most usual keywords representing the main topics on which papers are focused. A total of 537 distinct keywords (598 taking into account singular and plural versions) have been computed and analyzed from a list of 1193 records of keywords that were

Table 2. Main contributing organizations

Organization name	Number of papers
Polytechnic University of Catalonia	17
University of Texas at Austin	14
National Taiwan University	9
University of California, San Diego	9
FIGG Engineering Group	7
University at Buffalo, State University of New York	7
University of Castilla La Mancha	7
Northwestern University	6
National Chiao Tung University	5
University of Pittsburgh	5
Concrete Technology Corp.	4
Hanyang University	4
Merrimack College	4
National Taiwan University of Science and Technology	4
National Center for Research on Earthquake Engineering	4
T. Y. Lin International	4
Virginia Polytechnic Institute and State University	4
Washington State University	4
American Segmental Bridge Institute	3
Dowell-Holombo Engineering Inc.	3
Florida Department of Transportation	3
Massachusetts Institute of Technology	3
Parsons Brinckerhoff Quade & Douglas Inc.	3
Purdue University	3
Texas A&M University	3
University of Calgary	3
University of Nebraska–Lincoln	3

obtained from both kinds of sources, author keywords and KeyWords Plus. **Figure 6** shows the most frequent keywords, 39 keywords that have been used 5 or more times. As observed, "bridge(s)" is the most used keyword, followed by "pre(-)stressed concrete," "concrete(s)," "precast concrete," and "segmental construction." These 5 keywords represent 15.5% (185 out of 1193 records of keywords) of the total records, where all the main 39 keywords represent 42.5% (507 out of 1193 records of keywords). The remaining 498 keywords are distributed as follows: 14 keywords have been used 4 times, 36 keywords have been used 3 times, 82 keywords have been used twice, and 358 keywords only once.

It is noteworthy that the top positions correspond to keywords mainly related to materials and construction, whereas the first keywords associated to structural phenomena such as "design (structural)" and "seismic (performance)" appear in positions 6 and 13, respectively.

Topics

The contents of all papers have been sorted according to a single main topic per paper. This analysis is intended to offer an overview to help readers familiarize themselves with papers on concrete segmental bridges according to their main interest. **Figure 7** shows the rank of the 20 main topics identified. **Table 4** reflects which papers belong to which topic (the numbers in Table 4 correspond to the record numbers of the papers according to Appendix A). As observed, the topic Projects/Case Studies includes 42 papers, more than 1 in 6, that are related to the applicability of concrete segmental bridge technology.

Citations

This analysis shows changes in the number of citations over time and identifies the most-cited papers. An increasing trend is observed for citations (**Fig. 8**). This agrees with the increase in the number of papers on concrete segmental bridges and on concrete bridges (Fig. 1 and 2). Figure 8 shows a remarkable growth in citations beginning in 2010 (2014 accounts for papers published in 2014 and updated in WoS before April 17). Regarding the information provided as a citation report from WoS, **Table 5** summarizes the main data for both the concrete segmental bridge and concrete bridge databases. As observed, the average number of citations for concrete segmental bridge (3.2) is less than half that of concrete bridge (6.9), whereas differences in the influence of self-citations and number of citing papers are not significant when comparing both databases, as ratios involving "times cited" and "citing papers" are close, ranging from 2.0% to 2.5%. However, citations are relatively focused on fewer papers for the case of the concrete segmental bridge database: its h-index is 13 (13 papers—or 5.4% of papers on concrete segmental bridges—with at least 13 citations) which results in a minimum of 13^2 (169) citations (or 21.8% of total citations), whereas the h-index for the concrete bridge database is 65 (65 papers—or 1.3% of papers on concrete bridges—with at least 65 citations), which results in a minimum of 65^2 (4225) citations (or 12.4% of total citations).

On the other hand, **Table 6** includes the 23 papers on concrete segmental bridges that have been cited 10 or

Table 3. Distribution of records based on WoS Category

WoS Category	Number of records within concrete segmental bridge	Number of records within concrete bridge	Percentage within concrete segmental bridge	Percentage within concrete bridge
Engineering Civil	154	3212	63.6	65.3
Construction Building Technology	139	2126	57.4	43.2
Materials Science Multidisciplinary	25	1067	10.3	21.7
Transportation Science Technology	15	335	6.2	6.8
Engineering Mechanical	9	363	3.7	7.4
Materials Science Composites	9	480	3.7	9.8
Engineering Geological	8	123	3.3	2.5
Computer Science Interdisciplinary Application	7	161	2.9	3.3
Materials Science Characterization Testing	6	284	2.5	5.8
Mechanics	5	339	2.1	6.9
Transportation	4	136	1.7	2.8
Engineering Multidisciplinary	3	199	1.2	4.0
Mathematics Interdisciplinary Applications	2	37	0.8	0.8
Education Scientific Disciplines	1	9	0.4	0.2
Engineering Industrial	1	17	0.4	0.3

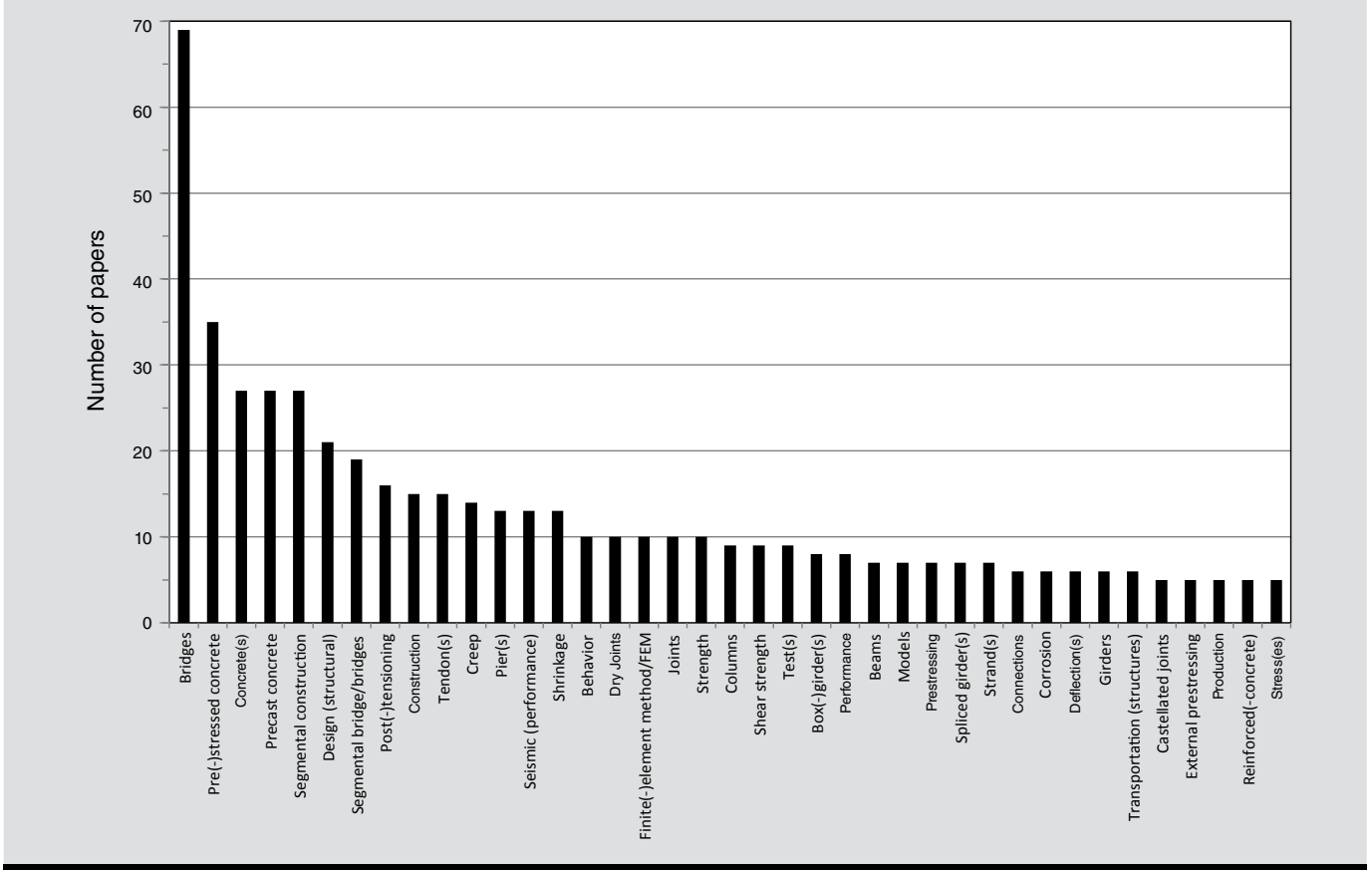

Figure 6. Ranking of keywords based on number of papers on concrete segmental bridges.

Table 4. Distribution of papers based on main topics

Main topic	Papers (record number according to Appendix A)
Projects/case studies	4, 15, 16, 33, 54, 68, 73, 76, 77, 79, 81, 84, 95, 96, 99, 107, 111, 127, 130, 133, 138, 145, 146, 156, 157, 159, 162, 167, 170, 171, 177, 187, 190, 192, 199, 204, 223, 233, 238, 240, 241, 242
Analysis/modeling	2, 3, 7, 9, 10, 11, 21, 27, 32, 34, 47, 52, 56, 60, 61, 90, 103, 117, 119, 131, 141, 180, 200, 210, 212, 216, 218, 220
Seismic	25, 35, 36, 41, 46, 49, 50, 51, 57, 62, 63, 88, 105, 122, 123, 124, 125, 137, 149, 150, 151, 152, 183, 191, 219
Time-dependent	14, 17, 18, 19, 20, 43, 44, 53, 58, 75, 80, 83, 92, 100, 115, 144, 154, 155, 173, 174, 194, 205, 230, 234
Construction technology	13, 26, 59, 70, 82, 89, 106, 110, 114, 118, 126, 134, 153, 158, 196, 198, 209, 217, 222
Joints	5, 6, 38, 85, 94, 101, 102, 112, 113, 135, 147, 211, 213, 214, 215, 221, 232, 237
Specifications/codes/design	12, 22, 29, 31, 65, 69, 71, 74, 78, 91, 97, 108, 148, 181, 188, 197, 239
Full-scale test	1, 8, 28, 45, 48, 104, 116, 121, 140, 169, 189, 201, 206, 224
State of art/review	24, 42, 67, 72, 98, 109, 120, 136, 163, 166, 202, 226, 228, 229
Durability	93, 129, 142, 160, 164, 165, 185, 186, 203, 227, 231, 236
Control/monitoring	23, 30, 40, 172, 182, 184
Reduced-scale test	64, 86, 139, 176, 208, 235
Temperature/thermal gradient	37, 87, 132, 175, 195
Aesthetics	66, 161
Biography	193, 207
Fiber-reinforced polymer	39, 168
Shape memory alloy	178, 179
Textile reinforced concrete	55, 128
Damage index	225
Lightweight concrete	143

Table 5. Citation reports

Parameter	Concrete segmental bridge database	Concrete bridge database	Concrete segmental bridge/ concrete bridge, %
Results found	242	4922	4.9
Times cited	775	33,955	2.3
Times cited excluding self-citations	528	26,591	2.0
Citing papers	502	20,332	2.5
Citing papers excluding self-citations	421	17,745	2.4
Average citations per item	3.2	6.9	46.4
h-index	13	65	n/a

Note: An h-index of 13 means that 13 papers had at least 13 citations.

Table 6. Summary of citation reports

Author(s)	Country	Record number according to Appendix A	Number of citations
Mari, A. R.	Spain	119	35
Billington, S. L.; Yoon, J. K.	United States	25	32
Aparicio, A. C.; Ramos, G.; Casas, J. R.	Spain	8	25
Chou, C. C.; Chen, Y. C.	Taiwan	46	23
Billington, S. L.; Barnes, R. W.; Breen, J. E.	United States	26	19
Seguirant, S. J.	United States	188	17
Ariyawardena, N.; Ghali, A.	Canada	9	16
Mari, A.; Mirambell, E.; Estrada, I.	Spain	117	16
Tadros, G.	Canada	204	16
Ou, Y. C.; Chiewanichakorn, M.; Aref, A. J.; Lee, G. C.	United States	152	15
Somja, H.; de Goyet, V. de Ville	Belgium	200	14
Buyukozturk, O.; Bakhoum, M. M.; Beattie, S. M.	United States	38	13
Roberts-Wollmann, C. L.; Kreger, M. E.; Rogowsky, D. M.; Breen, J. E.	United States	176	13
Robertson, I. N.	United States	173	12
Curbach, M.; Graf, W.; Jesse, D.; Sickert, J. U.; Weiland, S.	Germany	55	11
Shim, C. S.; Chung, C. H.; Kim, H. H.	South Korea	191	11
Taylor, A. W.; Rowell, R. B.; Breen, J. E.	United States	208	11
Turmo, J.; Ramos, G.; Aparicio, A. C.	Spain	213	11
Chou, C. C.; Hsu, C. P.	Taiwan	51	10
El-Ariss, B.	United Arab Emirates	60	10
Kim, T. H.; Lee, H. M.; Kim, Y. J.; Shin, H. M.	South Korea	105	10
Shushkewich, K. W.	United States	195	10
Wang, J. C.; Ou, Y. C.; Chang, K. C.; Lee, G. C.	Taiwan	224	10

more times, which cover 46.5% of citations (360 out of 775 citations). These 23 papers can be related to the first author's country: the United States has 9 papers, Spain has 4, Taiwan has 3, Canada and South Korea have 2 each, and Belgium, Germany, and the United Arab Emirates have 1 each. The remaining 219 papers can be grouped as follows: 4 papers with 9 citations each, 8 with 8 citations each, 9 with 7 citations each, 8 with 6 citations each, 6 with 5 citations each, 7 with 4 citations each, 16 with 3 citations each, 34 with 2 citations each, 30 with 1 citation each, and 97 papers were not cited.

Conclusion

This paper offers a pioneer bibliometric study on concrete segmental bridges that has been conducted based on 242 papers and reviews indexed in the WoS. The following main conclusions can be drawn:

- An increasing trend is observed in the number of papers published from 1968 (year of the first paper) through 2013. An increase in the relative presence of papers on concrete segmental bridges with respect to all papers on concrete bridges appears through1981; after 1981, a decreasing trend is observed. The most remarkable relative presence of papers on concrete segmental bridges occurred from 1973 through 1984.

- Forty-five journals have published papers on concrete segmental bridges. Five of them published 145 papers (or 60% of the papers on concrete segmental bridges); 4 of these 5 journals are published in the United States.

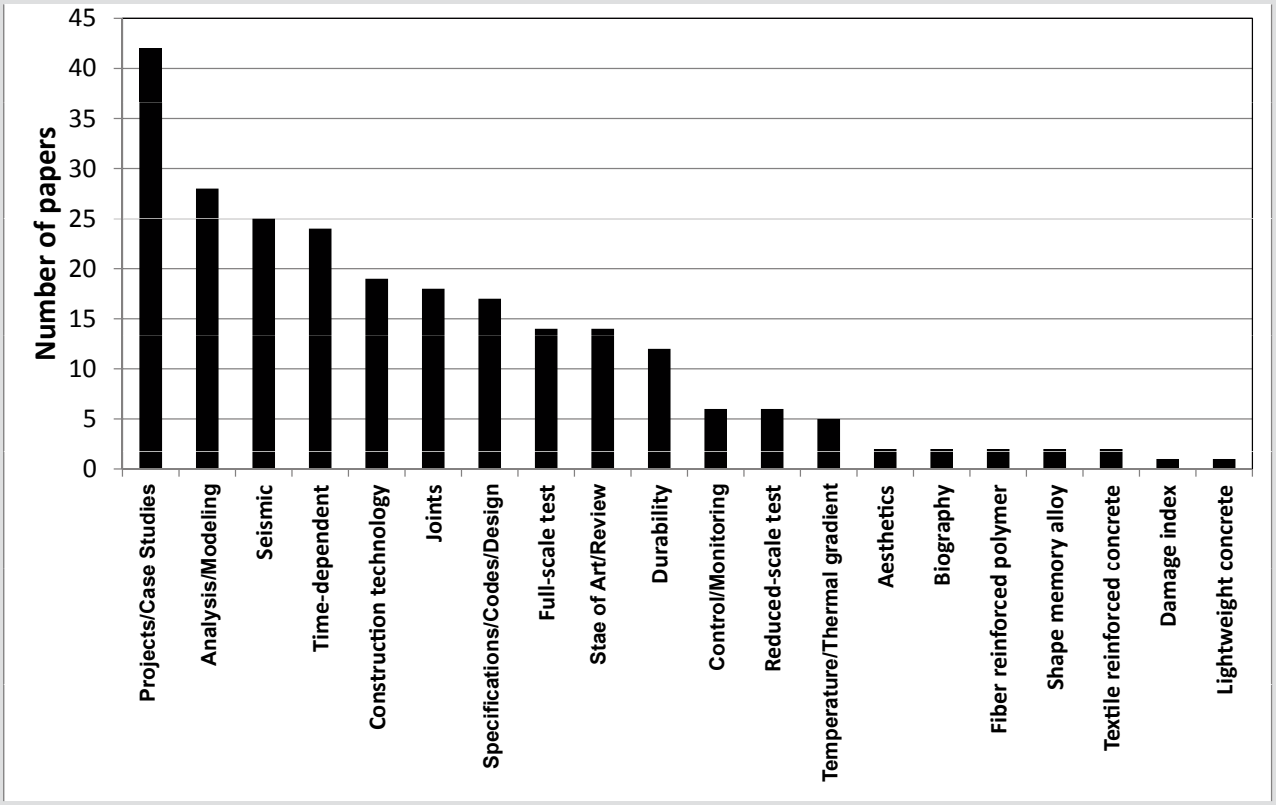

Figure 7. Ranking of main topics identified within concrete segmental bridge database.

- A total of 32 countries have been identified as contributors to research papers related to concrete segmental bridges. The United States leads the ranking with 135 papers (or 56%), far more than any other country. Only three other countries had more than 10 papers published on concrete segmental bridges: Spain (19), Taiwan (13), and South Korea (11). Since 1974, the United States commonly has had more papers on concrete segmental bridges than all other countries combined, and at the same time, the evolution of scientific production in the United States seems more regular. The U.S. contribution to the concrete segmental bridge field represents 6.3% of its total contributions to papers on concrete bridges. Both Spain (16.1%) and Taiwan (12.1%) have relatively strong presences in this field.

- Four hundred thirty-seven different authors have been identified. The top 20 contributing authors have 4 or more papers each and cover 20.7% of concrete segmental bridge papers. In 20.2% of the papers, these authors are listed as the first author.

- Two hundred thirty-two different organizations from academia, government, and industry have been identified as the affiliations of the authors of papers on concrete segmental bridges. The top 10 positions (having 5 or more records each) cover 22.9% of papers on concrete segmental bridges, with 6 organizations from the United States, 2 from Spain, and 2 from Taiwan.

- Seventy-two projects funded by 47 different agencies have been computed, 11 of which have funded more than 1 project. These 11 main agencies include 5 from the United States, 3 from Spain, 2 from Taiwan, and 1 from South Korea.

- Most of the screened papers are associated with three main WoS categories: Engineering Civil, Construction Building Technology, and Materials Science Multidisciplinary.

- A total number of 537 different keywords have been identified. The top 5 keywords represent 15.5%, whereas the top 39 keywords cover 42.5%. First positions correspond to keywords mainly related to materials and construction aspects, whereas keywords associated with structural phenomena appear in position 6 or lower.

- Twenty main topics have been identified as descriptors of the contents of concrete segmental bridge papers. The topic Projects/Case Studies includes 42 papers demonstrating the applicability of concrete segmental bridge technology.

- An increasing trend in citations is observed, with a remarkable growth in the number of citations beginning in 2010. Although the average number of citations of papers on concrete segmental bridges is less than half that of papers on concrete bridges, citations are

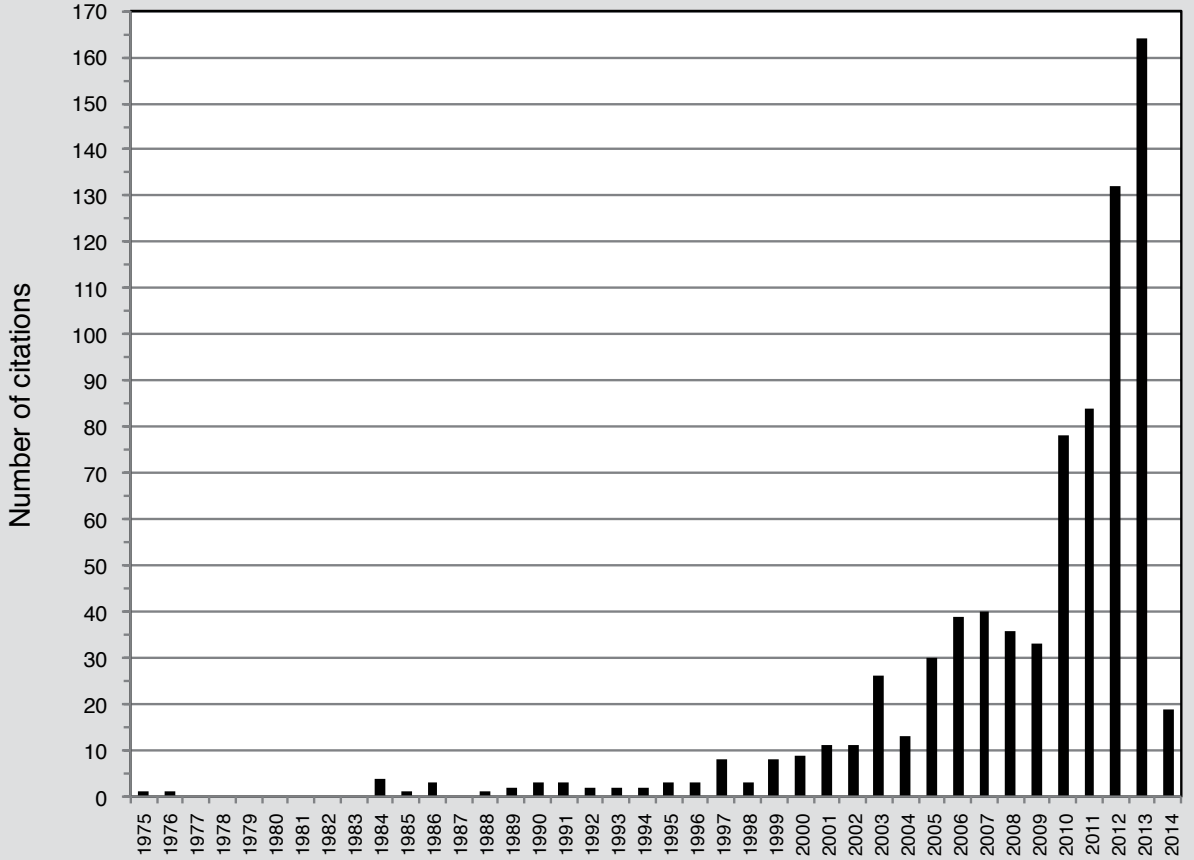

Figure 8. Number of citations of papers on concrete segmental bridges.

focused on fewer papers, which improves the h-index of the concrete segmental bridge database in relative terms.

References

1. Matt, P. 1983. "Status of Segmental Bridge Construction in Europe." *PCI Journal* 28 (3): 104–125.

2. Figg, L., and W. D. Pate. 2004. "Precast Concrete Segmental Bridges—America's Beautiful and Affordable Icons." *PCI Journal* 49 (5): 26–39.

3. Bennett, R. M., M. L. Hufstetler, and M. Carver. 2002. "50-year-old Prestressed Segmental Concrete Bridges." *Journal of Professional Issues in Engineering Education and Practice* 128 (2): 83–87.

4. Wilkes, W. J. 1980. "Segmental Bridge Construction—The Wave of the Future." *PCI Journal* 25 (5): 24–30.

5. Freyermuth, C. L. 1999. "Ten Years of Segmental Achievements and Projections for the Next Century." *PCI Journal* 44 (3): 36–52.

6. Barret, J. 2004. "Letter to the Editor on Precast Concrete Segmental Bridges." *PCI Journal* 49 (6): 143.

7. Harris, R. B. 1992. "A Challenge for Research." *Journal of Construction Engineering Management* 118 (3): 422–434.

8. Abudayyeh, O., A. Dibert-DeYoung, and E. Jaselskis. 2004. "Analysis of Trends in Construction Research: 1985–2002." *Journal of Construction Engineering Management* 130: 433–439.

9. Pritchar, A. 1969. "Statistical Bibliography or Bibliometrics." *Journal of Documentation* 25 (4): 348–349.

10. LIS Study Circle. "Bibliometrics: A Brief Introduction." Blog Archive of October 26, 2010. Accessed May 8, 2014. http://lisstudycircle.blogspot.com.es.

11. Cañas-Guerrero, I., F. R. Mazarrón, C. Calleja-Perucho, and A. Pou-Merina. 2014. "Bibliometric Analysis in the International Context of the 'Construction & Building Technology' Category from the Web of Science Database." *Construction and Building Materials* 53: 13–25.

12. Cañas-Guerrero, I., F. R. Mazarrón, A. Pou-Merina, C. Calleja-Perucho, and M. F. Suárez-Tejero. 2013. "Analysis of Research Activity in the Field 'Engineer-

ing, Civil' through Bibliometric Methods." *Engineering Structures* 56: 2273–2286.

13. Rojas-Sola, J. I., and C. De San-Antonio-Gómez. 2010a. "Bibliometric Analysis of Spanish Scientific Publications in the Subject Construction & Building Technology in Web of Science Database (1997–2008)." *Materiales de Construcción* 60 (300): 143–149.

14. Rojas-Sola, J. I., and C. De San-Antonio-Gómez. 2010b. "Bibliometric Analysis of Colombian Scientific Publications in Engineering, Multidisciplinary Subject Category in Web of Science Database (1997–2009)." *Dyna-Colombia* 77: 9–17.

15. Abudayyeh, O., A. Dibert-DeYoung, W. Rasdorf, and H. Melhem. 2006. "Research Publication Trends and Topics in *Computing in Civil Engineering*." *Journal of Computing in Civil Engineering* 20: 2–12.

16. Thomson Reuters Corp. Products & Services, Scholarly & Scientific Research. Accessed April 17, 2014. http://thomsonreuters.com.

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Abstract

This paper provides a bibliometric analysis of indexed scientific papers on concrete segmental bridges. Two hundred forty-two papers published from 1900 through 2013 were extracted from the Web of Science. The analysis examines author information, journal and year of publication, WoS category, funding agency, topics, keywords, and content. This study shows that the main references on concrete segmental bridges were published in United States journals on concrete structures; more than half were by authors in the United States.

Keywords

Bibliometry, bridge, journal, paper, review, segmental, Web of Science.

Review policy

This paper was reviewed in accordance with the Precast/Prestressed Concrete Institute's peer-review process.

Reader comments

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