Engineering the Permanent Material: Research and Applications of Concrete During World War I

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In 1904, the American Society for Testing Materials produced specifications for manufacturing cement. To test consistency, researchers were instructed to first create a paste by mixing cement with water, form it into a ball with their hands, and then complete the process by “tossing [the ball] six times from one hand to the other, maintained about six inches apart.” Resembling cooking rather than industrial manufacturing, early practices of cement testing were deeply inaccurate and unreliable. The making of concrete was similarly inconsistent, involving a haphazard pouring and mixing of various materials whose properties were virtually unknown and quantities poorly calculated. Research and application efforts of concrete during World War I radically transformed the making and testing of this “civilizing medium.” Indeed, American manufacturers reveled in the fact that while the invention of concrete could be traced to Europe, its elevation to a material of ubiquity rested in the expert hands of American researchers.2 Employing wartime scientific advances in geological research, testing, and construction, American scientists learned to engineer the material to build almost anything. This paper argues that the wartime investments that the American government, universities, and businesses made in concrete technologies cemented American dominance of the industry and shaped global knowledge of the material. By examining the work of governmental bodies and science organizations, like the Emergency Fleet Corporation and the National Research Council, alongside that of private players, like the Edison Portland Cement Company, the narrative brings to light the conflict’s transformation of the American concrete industry and its new positioning on the global stage. Finally, the paper aims to move beyond a historical retracing of events and considers pending theoretical questions about the role of material flows in transnational histories of capitalism, science, and the built environment. As contemporary urbanization

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1 A final step in the testing process included placing a rod atop the paste and letting it settle for ½ minute. If the rod sunk 10 millimeters into the material, the consistency was appropriate. American Society for Testing Materials, “Standard Specifications for Portland Cement,” adopted in 1904, p. 2, Smithsonian National Museum of American History.

efforts continue to rely on extensive uses of concrete, at times entirely depleting our material resources, it is critical to understand where the material comes from and what entities shape its production.

Although World War I radically transformed the concrete industry, scholars have overlooked this development almost entirely. Academics who dabbled in concrete's history have largely focused on architectural design and the emergence of Brutalist aesthetics in the 1960s and 1970s. Nationalist politics have also materialized a roadblock for histories of concrete. European scholars and architects, for example, have largely dismissed American contributions to both concrete production and its applications, suggesting that the nation's prioritization of assembly line building could not lend itself to concrete construction, which relied on highly skilled labor. British architectural historian Adrian Forty was the first to point to this cultural and political divide, arguing that European claims to concrete were a form of dismissal of American cultural dominance. Despite Forty's acute observations, many historians have continued to diminish or entirely ignore American innovations in concrete, instead focusing on French, English, and German transmissions of such knowledge. Even texts that center on the construction of concrete fortifications during World War I fail to mention applications of American tools in cement production and concrete construction, which were relevant not only during the conflict, but also throughout preceding years. Indeed, only American historian Amy Slaton has critically examined American concrete production and application practices prior to 1930, focusing on engineering education. Therefore, questions about how Americans engaged with and contributed to European and global concrete practices are unexamined and continue to propagate particular nationalist politics.

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4 Science and technology studies (STS) scholars have argued convincingly that technological systems are not static and change along with cultural formations. And as technologies increasingly come to mediate different social and political processes, it is critical to understand the ways in which they accumulate power. See Sheila Jasanoff, The Ethics of Invention: Technology and the Human Future (New York: W.W. Norton & Company, 2016); Michael Thad Allen and Gabrielle Hecht (eds.), Technologies of Power: Essays in Honor of Thomas Parke Hughes and Agatha Chipley Hughes (Cambridge: MIT Press, 2001); Jeremy Black, The Power of Knowledge: How Information and Technology Made the Modern World (New Haven: Yale University Press, 2014).

5 Recent several years in particular have seen an explosion in scholarship on Brutalism, both in Europe and in the United States. Many of these texts have attempted to define the movement, examine its roots and widespread dislike for its aesthetics, often focusing on particular cities as case studies. See, for example, Chris Grimley, Michael Kubo, and Mark Pasnik, Heroic: Concrete Architecture and the New Boston (New York: Monacelli Press, 2015); Elain Harwood, Space, Hope, and Brutalism: English Architecture, 1945-1975 (New Haven: Yale University Press, 2014); Kyle May and Julia van den Hout, Brutalism (New York: CLOG, 2019); Barnabas Calder, Raw Concrete: The Beauty of Brutalism (London: William Heinemann, 2016); Ben Highmore, The Art of Brutalism: Rescuing Hope from Catastrophe in 1950s Britain (New Haven: Yale University Press, 2017).


paper does not aim to fill the gaps or offer an American perspective, but instead challenges nationalist rhetoric and proposes a comparative study of concrete that tracks the transnational flow of ideas, plans, technologies, and materials themselves. The legacy of wartime concrete research and applications is visible today as the American concrete industry continues to define basic processes and equipment used in concrete construction across the globe and even in outer space.

While the paper focuses on the technological transformation of concrete during World War I, it intertwines the narrative with histories of capitalism, materials, and construction. It also embraces relatively uncommon methodologies for historians, analyzing hundreds of photographs produced to show what good concrete, in its production, testing, standardization, and application, looked like. These published and unpublished images were collected from seven archival repositories: the National Archives I & II, the National Archives at Kew, National Academies of Sciences – National Research Council, Thomas Edison National Historical Park, Smithsonian Museum of American History, and the Smithsonian Research Annex. The construction photographs, which are commonly set aside by historians as illustrations of labor performed, are employed in this paper as central evidence of the social and technological change that the industry experienced. Photographs of test outcomes are likewise examined as active sources of information. Like several other texts that examine visual artifacts in the study of science and technology, this project expands the purview of what can and ought to be considered as evidence in the study of materials.

Concrete Manufacture in Peacetime United States

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10 I am here referring to NASA’s experimentation with cement and concrete production, which could be employed in the future to build habitats in outer space. These efforts are driven largely by American resources and tools, including industry representatives like the Portland Cement Association. The latter has been conducting research on production of cement in outer space since the 1980s. NASA has also recently engaged in experiments to introduce its technology to cement production on earth: [https://technology.nasa.gov/patent/MFS-TOPS-68](https://technology.nasa.gov/patent/MFS-TOPS-68) (accessed August 19, 2018).
According to some provocative calculations, concrete is the second most consumed material on the planet. However, it is not really a material per se, but rather a mixture produced by employing different recipes depending on intended use. Specific quantities of cement, sand, gravel, and water are mixed, poured, and allowed to set in favorable weather conditions for a particular amount of time during which major compounds in cement form chemical bonds with water molecules. The production of concrete is therefore a complex and multifaceted process that necessitates a great degree of accuracy and consistency. It also involves the difficult extraction and manipulation of natural materials – while water, sand, and gravel can be acquired locally just about anywhere, cement must be produced by first extracting and then burning limestone at minimum 2,700 degrees Fahrenheit. This is partially why cement (and concrete) made its appearance on the American soils rather late in the mid-nineteenth century. Modern cement, produced in organized industrial plants, was originally shipped from England and Germany and was used sparingly mainly in the pouring of foundations; the rest of the structure would be built of wood, brick or other locally-available mediums. Prior to the nineteenth century, colonists and slaves produced a vernacular form of concrete called tabby, employing oyster shells for lime, however this method was much too labor intensive and failed to exert a significant national impact. In 1866, the first cement plant was opened in Coplay, located in the Lehigh Valley, PA. Referred to as the birthplace of the American cement industry and the crux of the so-called cement belt, the area reached the height of its productivity in the early years of the twentieth century, producing over 75% of the nation’s cement supply.

In the early 1900s, concrete was used broadly to construct infrastructural systems like roads, building foundations, structural supports, and waste management systems. In 1909, for example, the auto industry supported the use of concrete for the construction of streets in Detroit and Wayne County, which precipitated similar projects across the country. To expand its market beyond basic infrastructure, the concrete industry advertised that concrete was a clean, hygienic, and permanent material, free of the vile

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decay that afflicted wood and other porous surfaces. It was therefore employed in the construction of barracks, hospitals, and other environments concerned with the spread of disease. However, while concrete was quickly accepted as a construction medium, it failed to generate interest among architects and other professionals concerned with the aesthetics of the built environment. Eminent architects, including Frank Lloyd Wright, criticized the material, proclaiming that concrete had “neither song nor story.” Design media outlets similarly expressed disdain for the medium, describing aged concrete “to peel away in thin scales as if it were suffering from some disease” and rain damage leaving marks “as if it were bruised.” In other words, the medium on its own was repulsive, but if covered, painted, or treated with other disguises, it could be used effectively. The use of concrete was difficult not only because of its aesthetic deficiencies, but also due to regional inconsistencies. Indeed, concrete employed in infrastructure across the country deteriorated at different rates depending on the specific material properties of used ingredients. To prevent the delay of product distribution, the infrastructural grid had to be unified through the standardization of materials. As a result, questions regarding whose role it was to regulate the production of concrete and its use in interstate infrastructure became significant for the industry.

The broadly felt need to regulate the quality of the material on the national scale prompted the Bureau of Standards to produce specifications for cement in 1901 and contributed to the founding of the American Concrete Institute in 1905. Manufacturers also published a selection of industry-specific publications, like Cement, Concrete, and Cement Age, that informed their readership about appropriate mixing ratios and methods, transnational industry news, technological advances, and answers to problems regarding the production and applications of the material. The concrete industry’s efforts to spread the so-called “gospel of concrete” were not limited to a single medium or readership. Indeed, the industry quickly founded local and national exhibitions and tailored its message to a more novice

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audience. The year 1908, for example, saw the First Annual Cement Show, held in Chicago.\textsuperscript{19} While this was not the first time that the cement industry exhibited its materials in a show – states commonly held their own individual materials exhibitions – it was the first national independent effort by the concrete industry to coordinate exchange regarding new products among American manufacturers, users, and the public. Over 30,000 visitors showed up to the exhibit to see numerous booths filled with machinery and products that demonstrated the versatility of concrete. Alongside the show, meetings were held with industry experts from across the country who taught visitors about new techniques in testing and construction. The exhibits themselves were visually engaging, encouraging the potential customers to imagine their homes and farm buildings constructed out of concrete. One exhibit, for example, showcased a dramatic panorama of an idyllic street lined with trees and fashionable single-family homes (Fig. 1). Protruding display cases illustrated potential concrete contraptions that could be used for sidewalks and streets. The Cement Show therefore strategically expanded the concrete industry’s purview and cemented its position within middle-class notions of secure and remote suburban living.\textsuperscript{20}

In 1912, the government released official specifications for Portland cement, publishing requirements for its composition, fineness, soundness, consistency, time of setting, tensile strength, and testing.\textsuperscript{21} This produced the first specific set of regulations for what made concrete scientifically good. Some of the specifications were direct and obvious, for example, 92 percent of cement had to pass through the No. 100 sieve, and 75 percent through the No. 200 sieve.\textsuperscript{22} Other factors, however, were more difficult to define numerically. In particular, describing consistency and the required state of plasticity was a continuous challenge. No longer encouraging researchers to toss a ball of cement paste from one hand to the other, the report instead included photographs and drawings of the appearance of cement paste clumps of different consistencies. In 1916, prompted by the need for more uniform standards, the

government published a more specific set of definitions for concrete, describing six categories for a range of mixtures: dry, moist, plastic, quaking, mushy, and fluid. These early efforts of standardization illustrated the challenge of measuring a process that required a high degree of worker intuition and judgement. Despite manufacturers’ wishes of distinguishing the industry as deeply entrenched in the scientific method, laborers nonetheless were expected to tamper with concrete production to eventually learn what different consistencies looked and felt like. One publication accurately described the challenge of training workers to make good concrete: “of all the materials of construction subjected to a system of testing, cement is probably the most dependent on the judgment and skill of the tester, and with all our well-equipped laboratories, it is still impossible for us to remove the most important factor of personal equation.” Therefore, while the tools used to determine quality might have been new, the work itself relied on what Michael Polanyi called tacit knowledge – the ability to perform a skill without being able to explicate how it is accomplished. Historically, this form of expertise was dismissed as a type of servitude performed by collectives of men without political integrity rather than by scientists gifted with individual genius. In the production of concrete, tacit knowledge was dependent on local expertise since the properties of available aggregates and even water sources could have a marked effect on the final product. Although the knowledge and skill that was required of workers to produce good concrete was significant, their labor was dismissed as easily replaceable with new technologies and standardization efforts.

**World War I and the Transnational Concrete Industry**

Immediately upon entering the war in 1917, the Department of the Interior produced a special report that examined the country’s ability to extract and manufacture the necessary ingredients for concrete, including high-calcium limestone, marl, clay, shale, blast-furnace slag, and boiler ashes. The report found that while the necessary natural minerals were available in sufficient quantities in the majority of the states, production nevertheless lagged behind due to issues of cement mill distribution. Indeed, cement
production was constrained to several high-producing regions and monopolized by few companies that controlled the markets and transportation networks.\textsuperscript{27} Furthermore, opening and operating a cement mill had become exceedingly expensive, ranging from half a million dollars for a small plant to five or six times that amount for one of the larger plants. Despite the industry’s limited geographic span, Americans were nonetheless producing 30 to 40 percent in excess of domestic consumption. The Department anticipated that such overproduction rates would allow the industry to not only ship cement to its allies, but to also pursue trade with other countries in the West Indies, South America, and Asia – markets that had been largely dominated by European cement manufacturers. In addition to its potential for global distribution, the report concluded that concrete was a medium of “great military importance” due to its low cost, quick handling, durability, sanitary and fireproof qualities, and ability to set and perform well under water.\textsuperscript{28} Soon after the war started, the government labeled the cement industry as “essential” to the war effort.\textsuperscript{29} Therefore, at the start of World War I concrete was expected to perform both as a new military technology and also a political agent in furthering American economic and political interests overseas.\textsuperscript{30}

And it was not only the Americans that were enthused about the growth of their industry. While Germany kept up its high production capacity, the Allies struggled to sustain laborers in their cement plants and to acquire the necessary minerals and fuel.\textsuperscript{31} Great Britain, for example, had to resort to employing women, bringing Irish workers, and putting to work over 2,300 Prisoners of War in numerous

\textsuperscript{27} In many ways, the concrete industry in the early decades of the twentieth century fostered a natural monopoly, which necessarily depended on the high costs of business establishment, which precluded any local or even national competition. For more on the economic concept, see Robert Whaples and Randall E. Parker (eds.), \textit{Routledge Handbook of Modern Economic History} (New York: Routledge, 2013); Christopher D. Foster, \textit{Privatization, Public Ownership, and the Regulation of Natural Monopoly} (Hoboken: Blackwell, 1992).


\textsuperscript{29} Letter from the Edison Portland Cement Co. to its salesmen, September 3, 1918. Thomas Edison National Historic Park, Edison Portland Cement Co., I. Corporate Files, B. Correspondence, Box 26.

\textsuperscript{30} Concrete obviously was not the only medium employed by the US government to further national interests abroad. Megan Black, for example, interrogates the manner in which the Department of the Interior failed to limit its scope merely to the national interior and expanded its research and accumulation of raw minerals globally. Megan Black, \textit{The Global Interior: Mineral Frontiers and American Power} (Cambridge: Harvard University Press, 2018).

\textsuperscript{31} German concrete industry matured early and was performing exceedingly well prior to the breakout of World War I. In 1912, for example, German production levels compared to those of the United States, whereby the labor costs were half of those in the United States, and the cost of coal was twice as expensive. Despite similar production rates, Germany produced only half the cement it consumed, which meant that it could export the rest to create a regional and even global chain of material distribution. One report concluded that this was due to the way in which cement manufacturers had set reliable standards for the cement testing from the outset of the industry, which were officially introduced by the state. This led to an increased faith that architects and builders came to have in the material, which was then applied as a substitute for bricks and natural stone in countless projects. Manufacturers themselves employed the material in constructing their factories and warehouses, thus contributing to increased demand. Therefore, unlike American manufacturers, who had to spend an exorbitant amount of time, effort, and resources in creating and distributing propaganda about concrete, German citizens saw the benefits of the material on their own without the assistance of advertising. Letter from the President of the Thomas Edison Portland Cement Co. detailing the international cement production landscape and Dr. Otto Schott, “A Vital Question of the American Cement Industry” (1920s). Thomas Edison National Historical Park, Edison Portland Cement Company, I. Corporate Files, A. General Office Files, Box 25, Folder 124.
plants to produce cement.32 By 1918, the situation had gotten so dire that one plant in New Holland could not even maintain the minimum of six laborers necessary to keep the plant supplied with clay. Similarly, another plant in Arlesey could not meet its production goals due to obtaining only 50 percent of the necessary raw supplies.33 While British cement producers worked “from hand to mouth,” the situation in France was better in some respects: although shortage on output alone exceeded 14 thousand tons per month in 1918, many plants maintained respectable stocks of coal for cement production.34 One of the central issues in the European concrete industry was the small scale of production facilities, which were tailored to providing cement for small local projects rather than transnational building efforts. This meant that plants typically lacked the large kilns, silos, and other infrastructure necessary for storing and burning the ingredients. And the rapidly expanding military construction needs further overwhelmed cement businesses, rendering facilities expansion close to impossible. Another significant challenge was transportation: providing cement to the Atlantic Coast was particularly difficult, since the area contained no cement works or roads, and the railway was used exclusively for supplying the field with munitions.35 The only way to bring cement to the area to build pill-boxes, fortifications, gun emplacement, and revetments was through sea networks, which presented a plethora of other challenges.36

Due to their own material needs and the difficulties that Europeans experienced with cement production, Americans were quickly roped into European cement industry affairs. The American Expeditionary Force in France negotiated to take over four cement mills and administer them jointly with the local governments: Beaumont, Couvrot, La Souys, and Guerville. Americans were required to pay a flat rental of four percent on the capital of each factory plus royalty of five francs per ton of cement produced; the agreement would be terminated three months after peace was declared.37 The American government also authorized the formation of a cement production battalion consisting of 12 units that

32 Request to employ 2,300 prisoners of war in connection with the cement industry in Great Britain, 3/5/2018, National Archives at Kew, MUN 4/6573.
34 “French Portland Cement,” DAC Branch Memorandum, 1918, National Archives at Kew, MUN 4/6605.
35 While the issue of logistics in the context of World War I has been examined by several scholars, the distribution of cement on the Western Front has been left untouched. See Ian Malcolm Brown, British Logistics on the Western Front, 1914-1919 (Westport: Greenwood Publishing Group, 1998); Martin van Creveld, Supplying War: Logistics from Wallenstein to Patton (New York: Cambridge University Press, 2004).
37 The British too contemplated establishing channels for similar negotiations for acquiring cement mills for the British government but assumed that the French would not agree to this arrangement. “French Portland Cement,” DAC Branch Memorandum, 1918, National Archives at Kew, MUN 4/6605.
could take over struggling European cement works and render them functional (Fig. 2). Major Spackman was in control of these efforts and communicated directly with the War Office in Great Britain. He promised to do what the American industry was already performing on the home front – meet production demands and ensure the consistency and quality of cement produced. In addition to issues with production, Spackman was concerned with Europeans’ general attitudes toward construction – armies were regularly overbuilding their defense infrastructure rather than building for immediate, short-term need. He also started negotiations with the British government about importing cement from the United States. The idea ultimately turned out to be impractical since at least ten percent of cement was lost in transport owing to poor quality of sacks and in the process of loading and unloading the material. In fact, the issue of engineering an appropriate material to manufacture durable cloth sacks would persist throughout the war and inventors like Thomas Edison expended great effort in finding a solution to the pressing problem.

Despite the enthusiasm both on the Allied and American sides, the concrete industry did not fare particularly well in the first months of the conflict. Cement prices climbed to higher levels than at any time since 1899, which affected production and consumption patterns. Private cement producers, like Edison Portland Cement Co., were disgruntled with the control that the federal government exerted upon their industry. The government took some of the cement plants under its own control, demanded that all cement businesses operate six days per week including holidays, set nonnegotiable prices for materials, and prevented cement manufacturers from entering non-governmental contracts without going through the appropriate approval channels. As the war advanced, manufacturers experienced not only depleted stockpiles of cement and cloth sacks for storage, but also low levels of coal and fuel, which slowed down cement production and distribution. Edison Portland Cement Co. along with other businesses advised

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39 Letter to the Edison Laboratory describing testing procedures and challenges, Tomas Edison National Historic Site Archives, Edison Portland Cement Company, I. Corporate Files, A. General Office Files, Box 25, Folder 36.
40 Such hefty government control would have been particularly difficult for Edison to swallow as prior to the United States entering the global conflict, the inventor was interested in challenging the Sherman Antitrust Law, which prohibited agreements or actions that allowed a company to monopolize a particular market. Letter from the Thomas Edison Portland Cement Co. President mentioning a conversation Thomas Edison had regarding his plan in connection with the Sherman Law. Thomas Edison National Historical Park, Edison Portland Cement Company, I. Corporate Files, A. General Office Files, Box 25, Folder 124.
41 Letter from Edison Portland Cement Co. to its salesmen regarding the state of the industry, April 26, 1918. Thomas Edison National Historical Park, Edison Portland Cement Company, I. Corporate Files, B. Correspondence, Box 26. Other materials industries, like oil and coal, experienced similarly extensive shortages. The need to pursue oil deposits in the Middle East prompted the American government to urgently consider the issue of material self-sufficiency. More on the development of energy industries
their clients to order early in advance, so that they could “work in harmony with the government transportation needs.” Finally, the war draft sent over 2.8 million able-bodied adult males to fight in the conflict, and even more men volunteered, leaving cement producers a dearth of laborers who could operate and maintain cement mills. Black workers, who were thrust into the manufacturing process to replace white laborers, were often difficult to retain due to the poor working conditions and inadequate healthcare – an issue that often resulted in workers’ deaths, or what cement producers termed the “black plague.” However, unlike their European counterparts that gathered new working hands, American producers opted for technological innovation that could automate some processes and compensate for the diminished labor. Manufacturers concluded that the cement industry could never achieve full efficiency running on dated technology – progress could only be attained and maintained with the constant introduction of new machinery. And, as some scholars have convincingly argued, the introduction of new technologies meant not only an increase in production, but also the eventual destruction of craftsmanship and worker autonomy.

Thomas Edison, who by the turn of the century had established an international reputation as a tinkerer who left no field untouched, was a significant leader in advancing cement production technologies and testing practices before as well as during World War I. Although the man entered the business in 1899 after curtailing his efforts to obtain iron ore from low-grade New Jersey rock, he transformed the cement industry with his 1909 invention of a 150 ft-long kiln (Fig. 3). The design was broadly criticized by competitors for its potential structural failures, but it quickly proved to be critical in the context of transnational politics, see Peter A. Shulman, Coal and Empire: The Birth of Energy Security in Industrial America (Baltimore: Johns Hopkins University Press, 2015).


44 Letter from Edison Portland Cement Company to its salesmen, August 9, 1918. Thomas Edison National Historical Park, Edison Portland Cement Company, I. Corporate Files, B. Correspondence, Box 26.


46 Letter from Edison Portland Cement Co. to company president Mr. Mambert regarding new upgrades at the Edison plant, January 30, 1918. Thomas Edison National Historical Park, Edison Portland Cement Company, I. Corporate Files, E. Office of the President – S.B. Mambert Files, Correspondence and Interoffice Memoranda, Box 30.

47 Harry Braverman, for example, articulates in his important book the manner in which the adoption of technologies, science, and new management techniques not only transformed the product, but also the work processes in service of capital. See, Harry Braverman, Labor and Monopoly Capital: The Degradation of Work in the Twentieth Century (New York: Monthly Review Press, 1974); Karl Marx, Capital: A Critical Analysis of Capitalist Production (London: Swan Sonnenschein and Co., 1906); David Noble, Progress without People: New Technology, Unemployment, and the Message of Resistance (Toronto: Between the Lines, 1995).
producing the large quantities of cement demanded by the war effort. The rotary kiln, positioned to rest on a slight angle, consisted of sheet steel lined with firebrick. The raw material was fed into the upper end and as the material passed through the kiln, it burned at 2,500-3,000 degrees Fahrenheit. The raw material finally emerged from the lower, “burning,” end as small pallets of clinker that were then ground into cement. To accommodate his new invention, Edison altered his entire plant, installing low pressure turbines to complement existing engines, a waste heat boiler plant, a new automatic weighing device, and rolls for preliminary crushing of the raw material. In addition to the new kiln, eight combined tube-and-ball mills, the largest in the United States, were integrated into the plant. Four of them ground the raw material and the remaining four ground the clinker. Each of the tube mills were divided into two compartments: the first contained 15,000-20,000 pounds of steel balls while the second contained 70,000 pounds of “manganoid” balls that ground the material to an even finer degree. The fineness of the ground medium depended on the length of time the material remained in each compartment as well as the speed with which the material was fed into the grinding mill. Ultimately, the clinker was ground until 85 and 82 percent of it respectively passed through a 200-mesh screen. These new burning and crushing processes shortened production time, and, Edison claimed, the time required for the hardening of his cement. The changes that Edison materialized set a new standard for the operation of cement mills across the country.

The plant was not the only work site that experienced significant change. Indeed, companies invested in various technological upgrades in the quarry, like the installation of electric generators, boilers, and drills, that enabled a more efficient extraction process (Fig. 4). Most importantly, electrification contributed to savings in labor: the electric drill that could be operated by one man, for example, replaced steam-powered machinery that required multiple men to not only operate the tool, but to also shovel coal. Similarly to the electric drill, the crusher aided in resolving the so-called “labor nightmare:” the machine crushed limestone, conveyed it to the mill in camel-back carts, dumped it into a

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50 Letter to Thomas Edison from the company’s president providing updates on new technological upgrades and status of business for the year 1918. Thomas Edison National Historical Park, Edison Portland Cement Company, I. Corporate Files, E. Office of the President – S.B. Mambert Files, Correspondence and Interoffice Memoranda, Box 30.
hopper, and from the hopper with a belt carried it to the final destination (Fig. 5). This equipment, which cost the Edison Portland Cement Co. over $100,000 to install, replaced 22 men that loaded 50-90 tons per man. Edison’s company concluded that the future of the industry would rest in its ability to come as close as possible to the complete elimination of hard labor: “We must get in our labor saving devices all the way through or we are going to lose that class of labor which we today think is indispensable, namely, the foreigner, who is going to leave us, and when this condition comes we must be free of labor.”

World War I therefore prompted cement producers to view labor as a significant weakness that the industry could resolve only by integrating new technologies and all but eliminating manual work.

The construction site too experienced some innovation through the widespread integration of mechanical mixers and new concrete distribution techniques. Prior to this invention, four to five workers were employed to gather the ingredients and mix them with water. With the new technology, one laborer could be expected to man the machine. However, the most significant improvement on the job site centered on the efficient distribution of already mixed concrete, which enabled the scaling of construction projects. The Gravity System, which originated in California and later spread across the nation, relied on a central tower and a mobile spout (Fig. 6). The material was run up the tower and then dropped vertically 120 feet into a hopper and redistributed using pipe at an 18-degree angle. Whereas previously numerous laborers had to dump the concrete using buckets, metal carts, and shovels, the new concrete shoot could be manned by only three workers, one at the tower and two at the delivery end of the pipe. This new invention reduced the number of men used in the tamping of concrete by at least one-half and saved money by eliminating otherwise necessary construction of wooden scaffolding. The tool was not entirely ideal as it developed clogs that were difficult and dangerous to clean. Despite the hick-ups, wartime technological innovation transformed concrete production and distribution from the mountain to the construction site.

While the technological transformation of cement manufacturing undoubtedly improved the material’s quality and consistency, the expanding reach of the geological survey to locate limestone

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51 “The foreigner” refers to the immigrant workers who were central to the concrete industry. Executive Committee of Edison Portland Cement Co. thirteenth meeting, June 24, 1918. Thomas Edison National Historical Park, Edison Portland Cement Company, I. Corporate Files, E. Office of the President – S.B. Mambert Files, Correspondence and Interoffice Memoranda, Box 30.
deposits was likewise significant. The National Research Council was particularly instrumental in generating this transformation by encouraging state governments, professional organizations, and universities to pursue geological research in their states. The first geological survey was established in the early decades of the eighteenth century and some states, like New York, continued to update their findings as new technologies provided access to untapped mineral resources. Other states, however, had lapsed in continuity and some abandoned such research altogether (eight states, Delaware, Louisiana, Maine, Massachusetts, Nevada, New Hampshire, South Carolina, and Utah, had no surveys whatsoever). The National Research Council embarked on an aggressive campaign, presenting to state governments evidence that geological surveys could be useful not only scientifically but also economically: the discovery of non-metallic minerals useful for construction efforts meant significantly increased taxes and guaranteed long-term demand. A particularly notable example was the geological survey performed in Tennessee, where the discovery of rich limestone deposits in an otherwise unproductive district led to the founding of two cement plants in Nashville, one valued at $2 million and the other just over a half million. The National Research Council concluded that this publicly-funded discovery led to the social and economic transformation of the entire region. In other words, the reframing of the geological survey as not merely a scientific pursuit, but a money-making and modernizing mechanism for the South positioned the concrete industry at the center of regional revitalization efforts.

The transformations that took over the concrete industry, from the quarry to the job site, also led to a significant alteration of business practice. Since the federal government controlled the price of cement and demanded large quantities of it, companies like the Edison Portland Cement Co. could not expect to profit significantly from these sales. It therefore prioritized the selling of its surplus material stock first to international markets, then to local consumers, and only then to old contracts. And the

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54 Indeed, perhaps the single most important construction effort was the building of road networks. The National Research Council reported that the increase in vehicles skyrocketed from 1,700,000 in 1914 to 9,000,000 in 1930. The National Research Council Archive, States Relations: Studies: Status of Scientific Research.
56 The concrete industry had started expanding southward in the early 1900s, but mobilized its efforts particularly strongly during World War I. Indeed, the creation of the New South in the post-Civil War era focused on the integration of new “permanent” industries that would contribute to long-term economic gain rather than continue to rely on agricultural manufacturing. For a discussion of these efforts and their effects upon the natural environment in the South, see William D. Bryan, *The Price of Permanence: Nature and Business in the New South* (Athens: University of Georgia Press, 2018).
business networks between the United States and South America, particularly Brazil and Cuba, were by no means new – American farmers in the 1840s and 1850s had employed scientific experts and pursued aggressive agricultural programs to gain economic independence from Great Britain. The shift in business practice allowed Edison to charge higher prices for its exported product to South America. Consequently, the company’s shipments abroad increased over 350 percent from 1917 to 1918. To accommodate the diversity of interested consumers, Edison Portland Cement Co. developed special publications that acquainted foreign customers with the different types of materials and distribution methods that Edison offered. National trends were likewise comparable and the Portland Cement Association reported increased export activity with Cuba, Argentina, Chile, and Mexico receiving the greatest number of barrels of American cement. Edison also anticipated that once the conflict was over, European nations would need all the cement they could produce to rebuild their countries, which would leave a “clear field” for the United States to market its products to South America. In particular, Brazil and Argentina, markets traditionally dominated by German cement manufacturers, were now up for grabs as the nation’s damaged economy and reputation hindered trade. And the former expressed interest not only in receiving cement, but also specific plans and techniques to create its own concrete ship construction program. As the war came to an end, shipping costs were reduced, making transnational shipping of cement more economically feasible. Indeed, Edison Portland Cement Co. received requests to ship cement not only to South America, but also to Africa. Despite the invitations, the company ultimately restricted its shipments to markets in Puerto Rico, Cuba, and other nearby West Indian Islands, which it thought would be most accessible and profitable.
Even though the concrete industry struggled in the first year of operation under wartime conditions, it quickly shifted gears and adjusted to the new market. Indeed, despite suffering labor and material shortages, Edison Portland Cement Co. managed to continue to grow its production capacity by integrating labor-saving technologies. After taking a year to adjust to the new business landscape, the company shipped the equivalent number of barrels as it did in its best pre-war year of 1917. In 1919, Edison announced that the company had reached unprecedented business success, producing 1.2 million barrels of cement to meet domestic demands and shipping half a million barrels to foreign markets. Edison’s wartime dealings allowed the company to develop relationships with foreign businessmen who could receive the copious amounts of cement that Edison was now producing. The state of industry affairs more broadly was likewise encouraging and the Portland Cement Association predicted that American businesses would ship around 85 million barrels in 1919, suggesting that the major challenges slowing down the industry no longer centered on production or efficiency but on the distribution of cement to new markets.

Applications of Concrete in Ship Construction

The availability of reinforced concrete for the construction of fortifications, roads, and buildings, motivated the American government to build numerous impressive structures. However, the ambition of such projects paled in comparison to the design and construction of concrete ships – an effort so magical and improbable that some manufacturers compared it to Aladdin’s flying carpet. As conventional transportation networks were overburdened with military needs, the government decided that researchers ought to commit to designing vessels that could be built using cheap and easily available materials. This was also an opportunity to improve upon existing ship standards and create an indestructible ship. Due to its extensive availability, concrete was selected as the preferred material. However, making concrete float was no small challenge. On the professional side, it involved the establishment of new relationships

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63 A report from the Edison Portland Cement Co. reported that the company hoped to ship 1,300,000 barrels of cement, just slightly below its 1917 rate of 1,302,138 and well ahead of its 1914 numbers of 777,608. Thomas Edison National Historical Park, Edison Portland Cement Company, I. Corporate Files, E. Office of the President – S.B. Mambert Files, Correspondence and Interoffice Memoranda, Box 30.
between private manufacturers, laboratories, and state governments. In terms of research, concrete ships necessitated elaborate testing of the performance of cement and various aggregates in diverse environmental conditions. These new professional networks and research performed were critical for reimagining the utility of concrete more broadly: whereas previously the material was thought to be appropriate mainly for buildings and roads, new research efforts showed it could be engineered to bring forth only desired qualities for more demanding construction projects. Therefore, while concrete ships failed to replace steel vessels as initially hoped, the research involved in their production transformed the concrete industry, cementing its central position as the most versatile and accessible of building materials.

By the time Americans came up with the idea of applying concrete to ship construction, Europeans had been tinkering with the technology for over half a century. Frenchman M. Lambot, for example, built the first concrete boat in 1849 and exhibited it at the Paris World’s Fair in 1855. More recently, Norway’s 1917 launching of the first ocean-going concrete ship was both morally encouraging and scientifically useful. The US Bureau of Standards received Norway’s 9-foot model and drawings soon after the first voyage to study its methods of construction. American officials also communicated to the British regarding their concrete vessel construction standards, hoping to learn from European successes and failures. Despite the initial transfers of knowledge, both specialized and popular thinking about concrete vessels was seriously limited and almost entirely derived from experiences with concrete architectural construction, viewing a ship as a “40-story office building laid down on its side.” This widespread ignorance was most accurately illustrated by the roughly 170 letters of suggestions the Department of Concrete Ship Construction received from bankers, chemists, engineers, architects, and other hobbyists. While some ideas, like electro-plating the ships to prevent corrosion, were thought-provoking and useful, others, like the idea of making concrete lighter by using shredded newspaper as aggregate, were humorous at best. Indeed, the construction of concrete ships necessitated the radical

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67 Indeed, while the Emergency Fleet Corporation planned to construct 25, none were built for the war effort and only twelve were under construction. After the war, many of the vessels were sold off to private bidders to be used as barges or dismantled for scrap. See Tony C. Liu and James E. McDonald, “Concrete Ships and Vessels: Past, Present, and Future,” 1977 final report prepared for the Chief of Engineers office, US Army, [http://www.dtic.mil/dtic/tr/fulltext/u2/a045706.pdf](http://www.dtic.mil/dtic/tr/fulltext/u2/a045706.pdf) (accessed August 28, 2018).
69 Suggestions and Information, Department of Information and Files, 116-143, RG 32 Records of the United States Shipping Board, Box 9, National Archives I.
reconfiguration of testing practices, wooden forms, metal reinforcement, and concrete itself. An early
government report revealingly concluded that concrete ship construction was about 70 years behind that
of steel.\textsuperscript{70}

The design of the concrete ships was the most uncomplicated of decisions. The Emergency Fleet
Corporation decided to adopt the standard “ship-shape” to avoid any potentially negative reactions from
the government, workers, or the general public.\textsuperscript{71} The separation of interior spaces was likewise decided
by naval architects and structural engineers, who adopted standardized arrangements; only oil carriers
had special interior partitions that provided reserve buoyancy.\textsuperscript{72} Before any of the ships could be
constructed, extensive concrete tests had to be performed to ensure that the proposed designs and
concrete used were structurally sound. The first step in this process was the identification of laboratories
that could perform such work. The National Research Council sent representatives out to the field to
gather data and organize an inventory of all academic, private, and government-run laboratories across
the nation.\textsuperscript{73} They found that not only did the laboratories suffer from a lack of researchers, but those men
who had not yet been drafted felt demoralized as their work did not appear to directly contribute to the
war effort. The Council concluded that not only should more research endeavors focus on making
concrete lighter, but the work should also be publicized widely to attain the respect that other war efforts
enjoyed. Soon thereafter, industry publications described the ensuing research in detail, proclaiming that
the extent of the concrete testing performed at university and government-run laboratories was
unprecedented in scale in the history of material science and construction.\textsuperscript{74} These efforts were expected
to inform not only concrete ship construction, but all concrete building and engineering projects for years
to come.

\textsuperscript{70} Construction of Concrete Ships: Letters and Reports, Document No. 239, 65th Congress 2nd Session (Washington, DC:
Government Printing Office, 1918), National Archives I, RG 32 United States Shipping Board, Concrete Ship Section, Decimal
General Files, June 1917-March 1921, Box No. 69, Folder 324.

\textsuperscript{71} US Shipping Board, Emergency Fleet Corporation, “Report of the Design Branch: Concrete Ship Construction Section, Ship
Construction Division,” undated. National Archives I, RG 32 US Shipping Board, Concrete Ship Section, Decimal General Files, Box
No. 77, Folder 333.2, Design General.

\textsuperscript{72} Report on the design of oil tankers, April 18, 1918. National Archives I, RG 32 US Shipping Board, Concrete Ship Section, Decimal
General Files, Box No. 77, Folder 333.2.

\textsuperscript{73} Letter discussing the inventory of laboratories, 1918. National Academies of Sciences, National Research Council, General
Relations: Industrial Research: Projects.

\textsuperscript{74} W.A. Slater, “Structural Laboratory Investigations in Reinforced Concrete Made by Concrete Ship Section, Emergency Fleet
Corporation,” American Concrete Institute 15 (1919): 1-36. National Archives I, RG 32 US Shipping Board, Concrete Ship Section,
Decimal General Files, Box No. 77, Folder 333.2.
While laboratories performed important tests to examine how concrete would deteriorate under water and other difficult weather conditions, two major tests were of exceptional significance— the composition of the material itself and the strength of structural components built using particular recipes. The first test examined the quality of aggregates and the strength of concrete that they could produce. Whereas cement testing was common practice, aggregate testing had not been regularly performed prior to World War I. This was primarily due to a widely held belief that the aggregate, which occupied at least 75 percent of total concrete volume, did not have a significant effect upon the material since it did not undergo a chemical transformation. However, tests of concrete under water exposed that the quality and size of aggregates could have a detrimental effect upon the exterior surface of ships. Therefore, engineers experimented with a wider range of aggregates, for example, replacing sand and gravel with burnt clay and even brick. Samples of the aggregates were mixed with cement to form concrete cylinders that were crushed by a compressive machine to determine the material’s appropriateness for the particular construction effort. While all cylinders broke under pressure, good concrete exhibited good breaks with standardized aesthetics: a good break resulted in a well-formed cone shape, whereas bad breaks produced fractures or cracking at either ends or the middle of the cylinder. The latter results suggested that the concrete mixture was inappropriate for the expected pressure the structure ought to sustain (or cylinders were made erroneously). Testing of aggregates revealed that the substitution of regular river rocks with volcanic products, like pumice, could not only add strength to concrete, but also make it substantially lighter. These findings prompted the Emergency Fleet Corporation to fund an expedited search by the US Geological Survey for light-weight volcanic rock on American soils, discovering repositories in Cutter and Amboy, New Mexico, and Ash Fork and Nevin, Arizona.

The second test was no doubt more complex and labor-intensive, involving the preparation of mock concrete ship elements that were tested using a 100-thousand-pound machine, which applied increased pressure over a period of days. Upon breaking, the structure’s cracks were traced with a black

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76 Americans borrowed the idea of using pumice from German applications of the medium to the construction of buildings. H.A. Diehl, “Pumice as a Building Material.” National Archives I, RG 32 US Shipping Board, Concrete Ship Section, Decimal General Files, Box No. 139, Folder 537.1-17.
marker, labeled with different identifiers, and photographed for later examination (Fig. 7). The distribution of cracks and their patterns revealed important information about the spacing of metal reinforcements, which could be altered to improve the desired structural response. While in the case of a concrete building, the cracks can be problematic either for structural or visual reasons (in other words, cracks do not always suggest structural vulnerability), cracks in a ship prompted different, more severe, conclusions. Furthermore, the breaking patterns were not only photographed by researchers, but also sketched, graphed, and carefully studied to produce abstracted numeric equations (Fig. 8). The latter predicted the behaviors of metal brackets under different pressures, thus identifying points at which compression failure would likely occur if additional reinforcement is not implemented. More generally, the equations showed the way in which the moment of inertia, or the tendency of a body to resist angular acceleration, varied in any reinforced concrete structure. Disconnected from their origin and conditions of testing, the equations could support a significantly wider range of building projects than originally intended, thus rendering the material and construction techniques more widely accessible.

Although concrete ships failed to replace steel vessels, the research and testing efforts involved in these early applications did perform as the industry’s cotton gin, forever transforming concrete production and application. In particular, while cement testing was commonplace both in public and private laboratories, aggregate testing was in its very infancy prior to World War I. The need to find aggregates that could not only fill a volume but also add to the lightness and strength of the final product became a significant priority thanks to concrete ship construction efforts. Testing practices were also refined during this period, prompting the production of carefully staged photographs, sketches, and equations that detailed the methods for making and applying good concrete. Finally, the idea of constructing concrete ships was not entirely laid to rest in the postwar period. In 1942, the National Research Council once again mobilized the scientific community and sponsored University of California, Michael Lynch has written convincingly that photographs used in science contexts perform in very particular and distinct ways. They function not as illustrations, but permanent experiments that scientists can continue to work with and share with other researchers. The photographs that documented the structural weakness of concrete ship parts thus functioned as valuable sources of information both for ship and other construction projects. Michael Lynch, Art and Artifact in Laboratory Science: A Study of Shop Work and Shop Talk in a Research Laboratory (London: Routledge, 1985), 95. See also, Ann Thomas and Marta Braun (eds.), Beauty of Another Order: Photography in Science (New Haven: Yale University Press, 1997); Lorraine Daston and Peter Galison, Objectivity (New York: Zone Books, 2007).

Investigation of brackets, Files of Structural Research Section, Concrete Ship Department, Series 13, Folder 4, RG 32, US Shipping Board, Decimal General Files, Box 77.
Berkeley researcher R.E. Davis to visit cement testing laboratories across the nation and determine their preparedness for another round of concrete ship construction.\(^7\) The Council, in collaboration with the US Bureau of Standards developed regulations for producing light-weight concrete to be used in the new ship building efforts – standards that were largely based on research performed during World War I.

**Conclusion: Concrete after World War I**

After the conclusion of World War I, cement use in the United States climbed from 10 million barrels in 1900 to 94 million in 1920, and manufacturers determined that the industry entered a new era.\(^8\) They no longer had to prove the value of their product since wartime research, manufacturing, and application practices convinced the government, businesses, and the general public that the material could be engineered to perform well, even in the most unlikely projects. In particular, the National Research Council’s focus on geological research positioned the concrete industry as central to the reinvigoration of rural and otherwise minimally productive lands in the South. The Council convinced state governments that local economies could benefit enormously from discovering non-metallic minerals, including limestone, that could be used in the construction of roads, buildings, and other infrastructure. Concrete businesses were likewise transformed as a result of World War I. Since the government required companies to regularly fill quotas for cement, businesses like Edison Portland Cement Co. invested in technological advancements to loosen their dependence on human labor, thus all but eliminating hard manual work. Edison’s invention of the 150 ft-long kiln, the electrification of quarries, and integration of various machinery, from the electrical drill to the Gravity System, transformed concrete from the mountain to the job site. The companies’ imperative to make a profit off leftover cement stock prompted transnational business exchanges between American manufacturers and new markets in South America. Finally, unique applications of concrete, especially in the construction of concrete ships, led researchers to perform extensive tests not only on cement, but also on aggregates and in unique climatic conditions. This perfected researchers’ ability to generate equations that could aid in the positioning of metal.

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\(^7\) R.E. Davis, “Recommendations of Committee on Concrete Research to Division of Engineering and Industrial Research; Needs for Concrete Research in Connection with the War Effort,” June 26, 1942, Washington, DC, National Academies of Sciences, National Research Council, Engineering and Industrial Research, 1942-1943.

reinforcements. Such work was performed with the intention of informing not only ship construction, but also broader building efforts with concrete.

Wartime concrete research and application efforts rendered the material desirable not only for infrastructural, but also for architectural projects. National design media outlets agreed that concrete had arrived, surpassing its prewar limited applications to mundane and predictable factory construction: “Its progress to this point has been slow, for it was considered to be a purely structural material, too ugly to leave uncovered. (...) The engineer has devoted much time to reinforce concrete, but the architect has not given the same attention to its possible finishes.” It was now the responsibility of the architect to take the lessons that engineers and researchers delivered during World War I and uncover the material’s latent aesthetic potential. Famed architects like Frank Lloyd Wright, welcomed the challenge. The architect’s work in Los Angeles in the 1920s, for example, embraced both new production technologies and concrete to produce pattern blocks that were used to build the Hollyhock House (1921) and the Charles Ennis House (1924), among others. Wartime manufacturing work also led companies, including Edison Portland Cement Co., to enter the realm of domestic architectural design and construction. Most notably, Edison invented the single-pour construction method to produce concrete homes quickly and cheaply. He designed metal framework into which the material was poured consistently for six hours to complete the structure. The inventor planned to expand this endeavor by constructing interior features, from stairs to phonographs, of concrete as well. Despite these experiments of applying concrete for more affordable homes, it was the application of the material for a structurally daring affluent residence that had the most significant effect. Frank Lloyd Wright’s Fallingwater (1935), with its bold exposed concrete cantilevered floors that dramatically extended over the natural falls, signaled the permanent marriage of concrete and architectural modernity.

As concrete acquired more prestige in different professional circles, the National Research Council examined individual state accomplishments during the war effort. The organization was surprised

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to find that progress and its returns were not distributed equally. For example, agricultural states, largely located in the South, benefitted little from the research efforts. The Council also found latent institutional bias, whereby particular universities, especially the University of California at Berkeley, saw dramatic increases in government funding for its research efforts. While Berkeley’s prewar research budget compared to other universities’ at around a few thousand dollars, by the end of the war its budget ballooned to $80,000-100,000 and it took in more government contracts than any other university. The Council concluded that more work had to be done to bring both industry and science to other regions of the United States and thus democratize industrial engineering and materials science. Cement manufacturers likewise agreed that with northern states saturated with plants and increasingly costly labor, the industry would have to move southward in order to expand and tighten its business relationships with South American consumers. The Council sponsored the production and distribution of promotional media that advertised engineering jobs that citizens could pursue in the name of civil service. Cement manufacturers likewise published numerous booklets that showcased the different ways farmers could employ the medium to enhance their businesses. With greater numbers of geological surveys underway, more concrete businesses were established in states like Florida, Alabama, Louisiana, Mississippi, and Texas. Even contemporaneously, these centers function as major connective tissue for the global distribution of used concrete equipment.

The investment that American local and federal governments, universities, and businesses made in advancing research, testing, and engineering of concrete during World War I continues to shape the nation’s global positioning as a key knowledge society for the industry. Although the United States has been outpaced by China, India, and other heavy-hitters in concrete production and consumption, the country nevertheless continues to dominate the intellectual aspects of the global industry.

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85 It is important to note that several of these states were selected for the concrete ship building efforts. In particular, to avoid any interference with steel ship construction, five new ports were established in Wilmington, NC, Jacksonville, FL, Mobile, AL, San Francisco, CA and San Diego, CA. Therefore, while the South more broadly failed to acquire significant benefits from the research efforts, some southern states enjoyed the infrastructure that supported later transnational shipping activities. A.L. Bush, Layout and Equipment of the Government Concrete Shipyards, American Concrete Institute, Vol. 15, 1919, National Archives I, RG 32 United States Shipping Board, Concrete Ship Section, Decimal General Files, June 1917-March 1921, Box No. 69, Folder 324.
86 The recent claims by Vaclav Smil and popularized by Bill Gates regarding China’s outpacing of the United States in the concrete industry overlook the important role that the nation has carved out for itself in technological innovation. Bill Gates, “A Stunning Statistic About China and Concrete,” Gates Notes blog, June 25, 2014, https://www.gatesnotes.com/AboutBill-Gates/Concrete-in-
American scientific publications, including the so-called “concrete Bible,” which details the production of good concrete, continue to provide the most important and up-to-date information about making and working with the material. The texts are read widely around the world in American English. American higher learning institutions likewise continue to play a significant role as principle laboratories that engineer progressive versions of concrete: recyclable, self-leveling, 3D-printed, and void of water, among other variations. The research and application efforts of concrete during World War I therefore put the United States on a path to shape the material production of concrete not only nationally but also globally for years to come.

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Figures

Figure 1: A display of possible concrete street materials at the First Annual Cement Show in Chicago, 1908. While materials and trade shows were not uncommon for the early twentieth century, this was the first time that the concrete industry came together on the national scale to share products, research, and knowledge about the material. “First Annual Cement Show of the Cement Products Exhibition Company,” Cement 8 (9) (1908): 345. Smithsonian Research Annex.

Figure 2: American engineers construct a concrete dam in France to provide water to local hospitals and camps, April 1918. In addition to engaging in construction projects, American military officials took over some cement plants to produce the material for local consumption. National Archives II, Photographs collection, 111-SC-010170.
Figure 3: Edison Portland Cement Co. mill with the 150 ft-long kilns, which could produce substantially more cement than the standard 60 ft-long kilns. This was a critical invention that made large amounts of cement and concrete readily accessible for government projects and for export abroad. Undated photograph, Thomas Edison National Historical Park, Edison Portland Cement Co. records, unprocessed photographs collection.

Figure 4: A wooden model of Edison’s quarry in New Jersey showing the distribution of the new electrical network that brought drills and conveyors into the quarry to extract and move limestone to the mill. Undated photograph, Thomas Edison National Historical Park, Edison Portland Cement Co. records, unprocessed photographs collection.
Figure 5: Edison Portland Cement Co. two workers operate an electric crusher and conveyor system that extracts and transports limestone to the plant thus eliminating excessive hard labor. The technology was possible only through the integration of electricity into the operation of the quarry. Undated photograph, Thomas Edison National Historical Park, Edison Portland Cement Co. records, unprocessed photographs collection.

Figure 6: A laborer employs the new Gravity System concrete distribution device that allows him to handle 25 cubic yards of concrete per hour by simply directing the tool rather than shoveling concrete by hand or carrying the material in buckets. The System, originally invented in California, became particularly popular for large-scale wartime projects during World War I. Fred E. Engstrum, “The Spouting of Concrete,” the National Association of Cement Users, Proceedings of the Seventh Convention, 7 (1911): 529. Smithsonian Research Annex.
Figure 7: Concrete ship elements after the compression test with cracks and other damage highlighted with a black marker. The image performed not only as a documentation effort but a permanent experiment that could be shared with other researchers. Note that the background is entirely painted over as irrelevant noise that interferes with the test’s objective approach. National Archives II, RG 32 Records of the US Shipping Board, Box 32, Folder Series 1 – Pittsburgh Concrete Tests, Series 3 Ship Frame Tests.

Figure 8: A diagram produced by the Emergency Fleet Corporation on bracket tests – series 13, position of gauge lines and cracks, specimen C1, sheet 44. The diagram was produced by first analyzing the produced cracks, as shown in Fig. 7. The diagram was then used together with other gathered data to generate equations that could predict the effects of particular loads on concrete and the superior arrangement of metal reinforcements. National Archives I, RG 32 US Shipping Board, Decimal General Files, Box 77, Folder 4.