California Concrete, 1876-1906: Jackson, Percy, and the Beginnings of Reinforced Concrete Construction in the United States

Sara E. Wermiel
Boston Architectural College, Boston, Massachusetts, USA

ABSTRACT: This paper describes the early history of reinforced concrete construction in the United States. It traces the line of development from Thaddeus Hyatt through the engineer Peter H. Jackson and architect George W. Percy, to the constructor Ernest L. Ransome. Surprisingly, this occurred in the San Francisco Bay Area, far from the places where Portland cement was produced. Jackson was probably the first American to build Hyatt's patented reinforced concrete slabs. Percy and Ransome together created two of the earliest reinforced concrete buildings, in 1890-1891. Yet, after this, no all-reinforced building went up in the Bay Area until about 1906. Ransome moved his business east, and at the opening of the twentieth century, reinforced concrete buildings began to be built on the East Coast, by Ransome and others. Nevertheless, the few reinforced concrete buildings in the Bay Area, and the many buildings there with steel frames and concrete floors passed through the tremendous earthquake of 1906. The satisfactory performance of concrete in the 1906 earthquake and fire led to its widespread use in rebuilding San Francisco.

INTRODUCTION

An interesting aspect of the early use of reinforced concrete for building construction in the United States is that it occurred around the same time as in Belgium/France and Germany/Austria – the 1880s and 1890s – but early developments in America were independent of those on continent. In the first decade of the twentieth century, American engineers looked to developments in Europe when they began to create standards for reinforced concrete construction. But by then, the famous 16-storey Ingalls Building already had been erected in Cincinnati, from designs by the pioneer American reinforced concrete constructor, Ernest L. Ransome. This paper recounts the sources that led to Ransome's achievement, specifically, the links between Thaddeus Hyatt's famous 1877 pamphlet, *An Account of Some Experiments with Portland-Cement-Concrete Combined with Iron* … and Ransome's early work, which launched reinforced concrete as a building material in the United States.

THADDEUS HYATT (1816-1901)

The elusive inventor and reformer Thaddeus Hyatt has been accurately described as "one of those minor makers of history, well known and of considerable importance in their own time, who have faded into obscurity with the passing of years." (Langsdorf 1940, p. 227) His claim to a footnote in mainstream history rests on his activities in the 1850s as a leader in the movement to settle Kansas as a free state, meaning slavery would be banned. For his work in this cause, and his support of the militant abolitionist John Brown, Hyatt was ordered to appear before a committee of the U.S. Senate. When he refused to answer the committee's questions, he was jailed for over three months. About a decade before this, he patented an invention that made his fortune: an "illuminating vault cover," which was a panel made of iron and small glass disks, designed to cover cellars under city sidewalks so as to allow natural light into underground. After the Civil War in the 1860s, he lived mainly abroad, spending most of the time in England, and he continued to invent.

A problem that caught his attention was how to make cheaper, safer fireproof floors, in which structural iron was adequately protected from heat. From various sources, including William Fairbairn's well-known book, *On the Application of Cast and Wrought Iron to Building Purposes*, he learned of two French floors made of concrete and iron (the Vaux and Thuasne systems). In the nineteenth century, the term "concrete" referred to any

mixture of binder and aggregate that would harden; it was not a standard product and binders may or may not have included Portland cement. A few of the concrete floor systems, e.g., the Vaux system, and Matthew Allen and W. B. Wilkinson's flat slabs in England, were reinforced concrete, although of these three only the concrete in the Allen system contained Portland cement. (Brown 1966-67, p. 132) Seeking a new floor that would be superior to these, Hyatt conducted a series of experiments of iron embedded in Portland cement concrete in the 1870s. The results allowed him to understand how concrete and metal worked together, and what were the most efficient forms of metal reinforcing for floors. His main conclusions included the finding that flat, iron ties without flanges were sufficient to provide the tensile strength in iron-reinforced concrete floors, beams, roofs, and pavement slabs. He also found that iron and concrete expanded at about the same rate and that concrete, if made with proper Portland cement, was fire-resistive. Hyatt put his findings in the 1877 book, which he published himself, and he demonstrated the system by using it to build the floors in a building at 9 Farringdon Road, London (1876). (Spofford 1913, p. 214) Interestingly, through experiments in 1878-79, Hyatt found that using brick between the iron ties and rods of the grid, covered with cement, rather than concrete, made a stronger floor. (Hyatt 1880, p. 192)
Hyatt patented what he called "composition floors, roofs, and pavements" (U.S. patent 206,112) in 1878. The patent covered various forms of reinforced masonry, one of which was reinforced concrete, shown in Fig. 1.

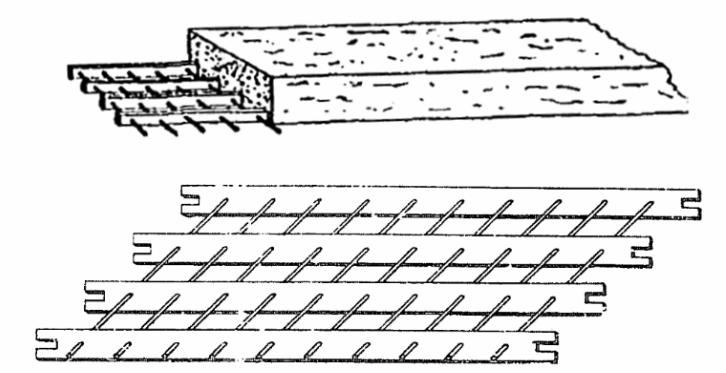

Figure 1: Hyatt's reinforced concrete floor (top) and reinforcement – a grid of flat ties threaded with wires, to create a bond with the concrete; (Percy 1888, p. 159; Patent No. 206,112, 15 July 1878)

Thus, in 1877, reliable information was available in Hyatt's book about a way to make reinforced concrete floors and beams. But was this publication known at the time? How widely did Hyatt distribute it? Hyatt included a copy with his application for the 1878 patent, and he publicized it in the American architectural periodical *American Architect and Building News*. His ideas seem to have had no impact on practice in England. Several of the concrete floor systems available in England in the 1870s were used by architects and builders. Hyatt also had little success getting English people to adopt his sidewalk lights. (Hyatt 1877, p. 63) No example of a Hyatt floor in an English building has been discovered, apart from those in his own buildings and a floor made with a combination of ideas from Hyatt and Matthew Allen (no doubt unlicensed by either). (Hurst 2001, 60) Nevertheless, Hyatt's pamphlet was to be the founding document of reinforced concrete construction in the United States, through the route of sidewalks.

PETER H. JACKSON (1829-1908)

The next link in the chain of influence from Hyatt to Ransome is the experienced mechanical engineer and ironworker, and prolific inventor, Peter H. Jackson. Jackson's family had been in the iron manufacturing business in New York City for many years, and in 1853, Peter joined his elder brother James in his foundry to form a business called James L. Jackson, Brother and Company. (HBS New York a) In 1857, this firm closed and Peter partnered with a moulder from the firm, A. J. Throckmorton, to form a new company, Jackson & Throckmorton, Architectural Iron Works, located at 55-67 Goerck Street. (HBS New York b) This firm advertised that it sold illuminated sidewalks panels under its own patent and did not have to pay a royalty to Hyatt. Hyatt countered with an advertisement warning Jackson's potential customers that they would still be liable to pay him a royalty. But soon, in 1860, this company dissolved and Jackson rejoined his brother to form the company James L. Jackson and Brother Iron Works. (HBS New York c) It manufactured a tremendous variety of products, from iron work for buildings, to machinery for ships, such as windlasses, winches, pumps, and steering apparatus. Among the firm's products, around 1870, was "patent illuminating tiles for sidewalks, areas, floors and roofs." (Boyd 1870, p. 71) During the 1870s, Jackson also worked as inspector of iron for the New York City building department, testing the strength of long iron beams and girders as required by law.
An economic depression that began in 1873 lasted much of this decade, slowing business in East Coast cities to a crawl. Whether because of a downturn in the foundry's business, or perhaps because Peter needed the money, or for some other reason, Peter sold his interest in the firm in 1874. Then, the following year, he made a big jump: Peter moved to San Francisco, where he began to making Hyatt's sidewalk panels of iron and glass under Hyatt's patents. (HBS California) Apparently Hyatt and Jackson had buried any bad feelings from the

1850s. Hyatt was living in Europe most of the time at this point, and his interests in the U.S. were handled by the firm Hyatt Brothers, a partnership between Thaddeus and his brother Theodore.
San Francisco was a young city growing at a fast pace, and it had many wide streets with wide sidewalks. The cellars of buildings extended under the sidewalks to the edge of the street – the subterranean vaults – and the sidewalks covering these vaults were normally made of wood. Obviously wood was not ideal for this purpose, and owners were beginning to replace their sidewalks with less perishable material. By the 1880s, the city government required owners to replace their wooden sidewalks.
Jackson offered owners his versions of permanent and safer sidewalks. With a partner, who was mainly an investor, Jackson established P. H. Jackson & Co. in San Francisco, for the purpose of manufacturing and selling Hyatt's patent illuminating tiles and other products. By 1884, he also offered reinforced concrete sidewalks, both plain decks and illuminated sidewalks. (See Fig. 2 and Fig. 3.)

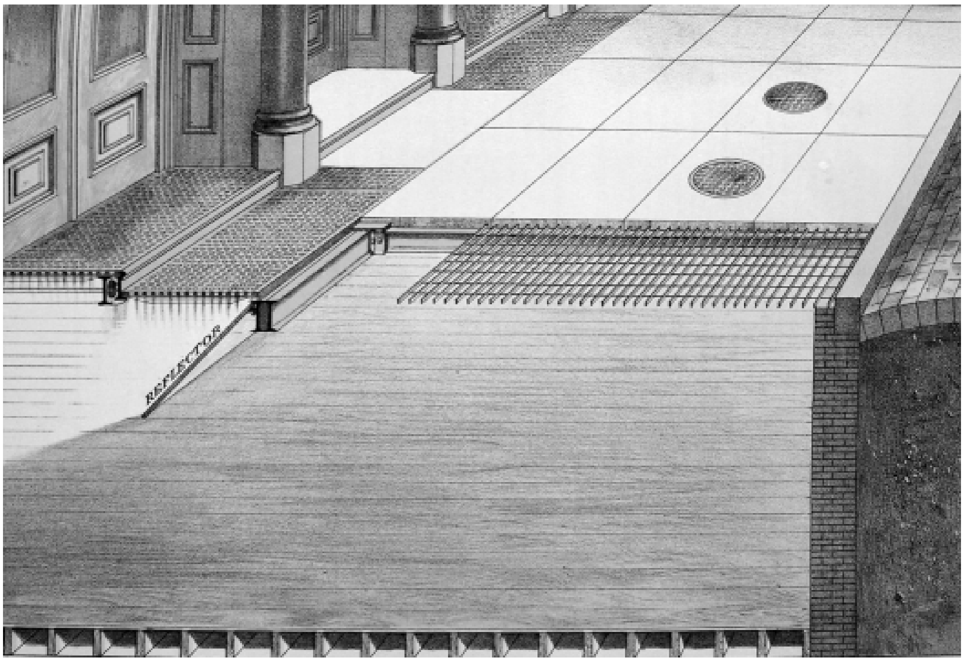

Figure 2: Illustration from P. H. Jackson & Co.'s catalogue, showing one of its products: Hyatt's concrete sidewalk reinforced with a grid of bars and wires; (P. H. Jackson & Co. 1884, plate 31)

Figure 3: Example of an illuminating tile made of concrete and glass; (S. Wermiel, photographer)

To demonstrate the merits of reinforced concrete slabs, Jackson conducted several tests in late 1883 and early 1884 in San Francisco. Two tests involved a Hyatt-style illuminating panel, made of small iron bars threaded with wires, and studded with lenses. A third was made of a solid panel. All the panels proved strong enough for use as sidewalks and floors. (Jackson 1884, pp.165-166) Jackson presented test results to the Technical Society of the Pacific Coast in August 1884. He published an elaborately illustrated catalogue advertising this and other products and assemblies he manufactured in 1884: *Text Book of Vault Construction and How to Improve Valuable Business Property in San Francisco*.

Interestingly, Jackson wrote that these sidewalks had been used extensively in large East Coast cities, and it seems logical that other Hyatt patentees would be building the concrete vault covers, as Jackson was beginning to do. But Jackson did not name any companies, and surprisingly, as yet no evidence that other companies were doing so has turned up. The New York firm Tice & Jacobs took over Hyatt's business around 1880; in the 1880s, this firm and a couple others in New York City (Dale Tile Manufacturing Co. and Jacob Mark) offered "concrete illuminating tile." This product consisted of an iron frame filled with concrete around the lenses to create a waterproof and non-slippery surface; it was not a reinforced concrete panel. Perhaps Jackson claimed his novel product was being used by businessmen in the established East to reassure potential customers. Rather, it seems that Jackson's firm was the first, and briefly the only, one to make reinforced concrete decks and other structural parts in the early 1880s. Frank Kidder, author of a widely used and frequently updated *Architect's and Builder's Pocket-book*, concurs; he wrote in the 1895 edition, "The only person in this country to make practical application of the method devised by Mr. Hyatt [gridiron and concrete], so far as the author is aware, is Mr. P. H. Jackson of San Francisco, Cal., who has used it quite extensively in that city for covering sidewalk vaults, and for the support of store lintels; also for self-supporting floors." (Kidder 1895, p. 450)
That this development was taking place in California, far from the sources of Portland cement, is a curious fact. Jackson invited professional men to witness his tests, one of whom was the architect and fellow member of the Technical Society, George W. Percy.

GEORGE W. PERCY (1847-1900)

Trained as an architect in his native state of Maine, and with experience working in Chicago and Boston, George W. Percy moved to San Francisco roughly at the time P. H. Jackson did, around 1875 or 1876. Probably he went west for the same reason, too: the shortage of work on the East Coast, as the economic depression dragged on. Percy worked for himself for a few years and then in 1880 formed a partnership with another young architect transplanted from Maine, Frederick F. Hamilton. The firm Percy & Hamilton lasted until the Hamilton's death in 1899.
Percy gained a reputation in the Bay Area for his construction expertise and was a leader in the design profession there. As a fellow architect wrote of him in an obituary, "His skill and experience have … been frequently sought in consultations involving question concerning architecture and construction." (Wright 1901, p. 31) Percy was a founding member of the Technical Society of the Pacific Coast, organized in 1884, and served over time as a director and as President. He wrote several technical papers about construction, ancient and modern. At one of the first meetings, Percy proposed P. H. Jackson for membership, and soon after, Jackson presented his paper on iron and concrete construction, describing the tests that Percy had witnessed. Jackson also shared his copy of Hyatt's 1877 pamphlet with Percy.
Percy was impressed with the strength of the Hyatt/Jackson panels, but he was concerned about the holes punched in the tie bars, which decreased the metal area, and the labor required to make the grid, which increased its cost. Meanwhile, another member of the Technical Society, and a man with long experience working with concrete – Ernest L. Ransome – began devising variations on Hyatt's patent. Ransome was the son of Frederick Ransome, a long-established artificial stone manufacturer in England, and he had come from England to the California around 1870 to work for the Pacific Stone Company, San Francisco, which had a license to make stone by the Ransome process. While the Ransome process at the time did not involve Portland cement, by 1882, Ransome was making sidewalks using Portland cement. These were conventional concrete arches between iron beams. But learning about the Jackson/Hyatt system gave him new ideas.
For a building he designed in Stockton, California (1883), Percy asked Ransome to produce a less expensive type of self-supporting sidewalk. It was in connection with this project that Ransome conceived an elegant solution: twisting square bars of iron. As reinforcement, the twisted bars created a bond with the concrete all along their length, and they were much cheaper to make than an iron grid. Ransome patented his invention in 1884, which he called "Building Construction," intending that it be used in buildings, not only sidewalks. (Ransome et al. 1912, pp. 290-291) Percy wrote that Ransome had for several years previous to this been using old wire ropes (the sort used by cable cars) as a bond in concrete walls – perhaps he knew of Wilkinson's system – and these wire ropes may inspired the idea for the twisted bars. (Percy 1888, p. 160) In the drawing for his 1884 patent, the reinforced slab is shown vertical, like a wall rather than a floor. (See Fig. 4)

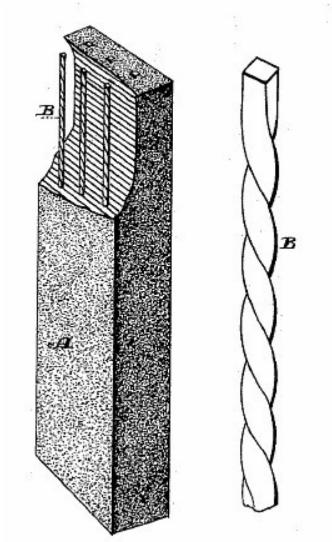

Figure 4: Ransome's twisted bar used to reinforce concrete; (Patent No. 305,226, 16 September 1884)

In 1884, Ransome conducted tests of his system, which Percy witnessed, which were reported to the Technical Society. One was of full-size section of a sidewalk, consisting of an unreinforced concrete arch 5 feet 6 inches (1.68 m) wide, 15 inches (38.1 cm) deep at the bottom of the arch, with one twisted iron bar in each side, 2 inches (5.1 cm) from the bottom. From this test, Percy derived a rule for the breaking weight of such an arch and analyzed the efficient placement of reinforcement in concrete. (Percy 1888, p. 161) By 1888, 50,000 linear feet of sidewalk over vaults, with spans of 10 to 22 feet (3 to 6.7 m), had been laid, with no failures.
From the results of Jackson's tests and those in Hyatt's book, and evidence from the concrete sidewalks built in San Francisco by Jackson and later Ransome, Percy became a convert to reinforced concrete, and he explored various applications of reinforced concrete to building. He used reinforced concrete to make lintels over store fronts 15 feet (4.6 m) clear span, carrying three stories of brick walls and wood floors. He built lavatory floors of 6-inch (15.24 cm) flat slabs, reinforced with small iron rods 6 inches on center. And he put concrete floors in other buildings, both flat slabs and arched. He also designed a reinforced concrete cistern for a private home. (Percy 1888, p. 161-162)

ERNEST L. RANSOME (1844-1917)

Except for projects for Percy, Ransome received few commissions to build in reinforced concrete, above the ground level. One project was a fireproof warehouse for the Arctic Oil Company works in San Francisco, built in 1885. For this he made a roof of concrete arches of uniform thickness, with iron bars in the springing where the arches met. At this time he also patented a concrete mixer and started to sell concrete machinery, as well as continuing to work as a contractor.
In 1888, Percy hired Ransome to build reinforced concrete floors in two important projects: the Bourn & Wise wine cellar and the California Academy of Sciences building (1888-1889). The Bourn & Wise building, in St. Helena, Calif., was a large, three-story structure; it had stone bearing walls, while the foundations and retaining walls for the hill behind the winery were made of plain concrete. The innovative part of the structure was second floor and driveway at this level, which spanned 15 feet (4.6 m) between the building and the hill behind. These were made of segmental arched concrete panels, about 25 feet (7.6 m) long and 7 feet 4 inches (2.2 m) wide, that were reinforced at the springing with 4 twisted bars. The bottoms of the arches rested on iron columns, two rows of which ran down the length of the building. Percy wrote that the concrete floor was very strong and non-absorbing, and helped moderate the temperature in the winery. (Percy 1894, p. 14-15)
The next project on which Percy collaborated with Ransome was the California Academy of Sciences building in San Francisco, begun while work on the Bourn & Wise cellar was finishing up, and completed in 1891. In 1888, the Academy held a competition for the design of a new rental office building and museum. Percy & Hamilton's entry was not the Board of Trustee's top choice, but the Board elected Percy superintending architect for the building. (Leviton et al. 1997, p. 297) Percy became the building's architect, creating the as-built design and superintending its construction.
The Academy had a relatively deep lot on Market Street, a principal street, and after trying unsuccessfully to get adjoining landowners to allow access to the rear of the lot, the Academy decided to erect two buildings, one behind the other, with access from Market Street. The museum would be in the rear, separated from the office building by a courtyard. While the Market Street office building was to be conventional construction, the museum building was to be fireproof. As built, it had bearing, brick walls, cast iron columns, and Ransome's concrete floors, with an open 5-story atrium in the center. Percy persuaded the Board to authorize reinforced concrete rather than standard hollow tile, because it would be cheaper. However, some people opposed using concrete, and Percy and Ransome conducted a load test on part of the floor to prove its merit. In November 1889, the Board heard a report on the test, which "found [the tested floor] in first-class condition." (Le-

viton et al. 1997, p. 305) The floors were made of concrete beams 15 feet apart with flat panels, 8 inches thick, between them; the underside was plastered directly on the concrete, and the tops of the floors originally were finished with a layer of colored cement, although later covered with wood. Balconies reinforced with twisted rods, cantilevered from the atrium floors, were later. (Percy 1894, p. 15)

As this project was being completed, Percy and Ransome undertook what turned out to be two landmark projects: the first all-reinforced concrete structures built in the United States since the William Ward house (1873-76), making these the second and third reinforced concrete buildings in America. Both were for the campus of the new Stanford University in Palo Alto, California. One was the Leland Stanford, Jr. Museum (1889-1891), built by the Stanfords as a memorial to their son. Jane Stanford insisted that the building's design be based on that of the National Archaeological Museum in Athens, Greece, and hired Percy & Hamilton in late 1890 as architects for it. Mrs. Stanford wanted the museum open in time for the beginning of the university's first session, in fall of 1891. (Osborne 1986, pp. 96-99) Percy proposed building the structure entirely of concrete rather than the sandstone used for the other university buildings. Thus, the walls, partitions, floors, roof, and dome were made of concrete with reinforcing bars (it did not have interior columns). The cement of the exterior walls was colored and scored with lines and partly tooled, so that it resembled the sandstone-work on the other buildings. (Percy 1894, p. 15) (See Fig. 5)

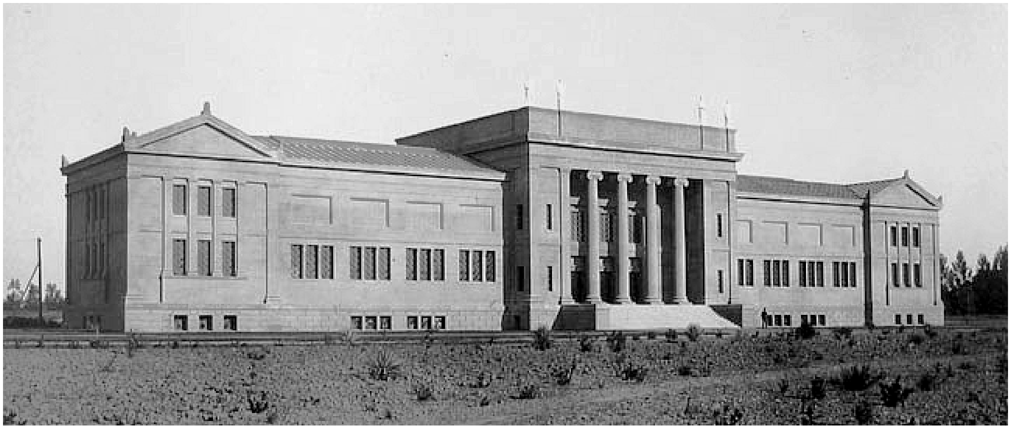

Figure 5: Leland Stanford, Jr., Museum, c 1891; (Courtesy of Stanford University Archives, GP Box 32, 6182)

Figure 6: Women's dormitory, Roble Hall (before 1906); (Courtesy of Stanford University Archives, A045 p. 3)

Percy and Ransome introduced various measures to prevent cracking and shrinkage that was common in monolithic buildings, but had limited success. Also, hollow spaces were molded in the walls to reduce moisture penetration and make them less resonant, with more success in the former than the latter. Percy believed the building's roof to be the world's first exposed reinforced concrete roof; it consisted of large tiles supported on iron trusses. Over the central pavilion was a low, flat dome that spanned 46 by 56 feet (14 by 17.1 m), made of concrete ribs and rings. The spaces in the dome between the frame members were filled with thick glass. The building was completed in 7 months. (Percy 1894, pp. 15-16)

While Percy was working on the museum, Jane Stanford asked him to redesign the university's women's dormitory, which was so far behind schedule that it would not be completed by the beginning of the school term. In this case, Percy recommended reinforced concrete for the sake of speed; Ransome was the contractor for the new design. In style and finish, the completed building, Roble Hall (1891), looked like the stone buildings on the campus. Most remarkably, it was completed in about three months. (Percy 1894, p. 16) (See Fig. 6)

SAN FRANCISCO EARTHQUAKE AND FIRE OF 1906

Ransome and a few other contractors built several small reinforced concrete buildings in the Bay Area before 1906. One of Ransome's projects was an addition to the Borax Works in Alameda, Calif. (1889), in which he built a ribbed concrete floor and reinforced concrete posts, probably the first in the U.S. The U.S. government built a concrete torpedo station on Yerba Buena Island. (Percy 1894, p. 16) In San Francisco, the California Wine Association Building (Casa Calwa Warehouse) had floor beams and panels made of stone concrete. And in 1906, a multi-story, reinforced concrete warehouse was under construction for Bekins Van & Storage Company. (Estes 1911, pp. 20-21)

As this list indicates, between the early 1890s and 1906, very few reinforced concrete buildings were erected in the Bay Area, or indeed, anywhere on the Pacific Coast north of Los Angeles. What caused the region's early start to stall so dramatically? There is no definite explanation; a number of possible reasons might be citied. One is that Ransome left the Bay Area when he went east to build a plant for the Pacific Coast Borax Co. in Bayonne, New Jersey (1897-98). From this point, he seems to have worked in the east. Secondly, building trades unions, which were very powerful in San Francisco at the time, evidently opposed concrete construction. So did businesses that competed with concrete, as one contemporary explained: "the steel and brick influences of San Francisco have been sufficiently powerful to exclude it from that city and neighborhood." (Crafts 1906, p. 168) San Francisco's building laws did not forbid reinforced concrete, but building officials may have acceded to the wishes of organized labor. Also, an economic depression in the mid-1890s slowed construction generally. But around 1900s, reinforced concrete buildings began to sprout up on the East Coast after, due in large measure to Ransome, who designed buildings there and licensed builders to use his methods. There was no such revival in San Francisco before 1906.

And yet, San Francisco did have another form of concrete construction: reinforced concrete floors in steel-frame buildings. These floors were put in a different structural category than all-reinforced concrete structures; they were fillings between steel beams and were part of steel-frame construction, used principally in skeleton-frame buildings. In fact, many of San Francisco's modern high-rise buildings had concrete floors, made with a variety of systems. The concrete in these floors usually was not stone concrete.

Thus, when the great earthquake and fire struck San Francisco in April 1906, there were a handful of reinforced concrete buildings and a few dozen steel-frame buildings with concrete floors in the path. One of the great questions after the earthquake was the comparative performance of buildings built in different ways, but especially impact of vibration and fire on the modern buildings. The reinforced concrete buildings came through the ordeal very well. Palo Alto suffered strong vibrations, but no fire. Buildings and structures of ordinary construction on the Stanford campus were damaged to some extent, a few of the conventional buildings came through with less injury. But Percy and Ransome's museum and women's dormitory survived largely uninjured. At Roble Hall, the chimneys, which may not have been reinforced, fell and damaged the roof and floors where they hit. The original section of the museum – the reinforced concrete part that Percy and Ransome built – lost a statue from its front façade; that, and damage to some interior finishes, was the extent of the damage. In San Francisco, the partly-built Bekins warehouse was the only structure still standing in its neighborhood, after the earthquake and fire. The California Academy of Sciences building also survived the earthquake and fire, but suffered damage from dynamiting of the Market Street.

There was a diversity of opinion in the many reports on the performance of building materials and assemblies that appeared after the earthquake and fire. Observers interested in reinforced concrete all noticed that the few reinforced concrete buildings came through the earthquake as well as any other buildings. Moreover, although there was debate on this point, the concrete floors in steel-frame buildings in San Francisco survived the fire and earthquake, and by most accounts performed as well as did the hollow tile floors. Consequently, after the fire, use of reinforced concrete increased significantly in the Bay Area. Nearly all steel-frame buildings erected after the fire had concrete floors. Moreover, the city began to issue permits to build reinforced concrete building; permits for 132 had been issued by mid-1910. (Leonard 1911, p. 40) There were still obstacles to building with reinforced concrete as late as 1911, but these only slowed down the use of concrete. The floodgates were open.

CONCLUSION

By the turn of the century, Americans could look to Europe as well as to their own growing stock of concrete buildings for information about the use and performance of the material. Indeed the first decade of the twentieth century saw an explosion of interest in reinforced concrete. It began to be used for every kind of structure, from bridges and marine foundations, to fences and tanks, on the West Coast as well as on the East Coast. The Cement Age had arrived.

George Percy did not live to see it, having died in 1900. Peter Jackson lived a long life; he must have been disappointed that his system of concrete construction did not catch on, the way Ransome's did. But he continued to patent inventions practically until the day he died. Ransome moved east around 1897 and had an illustrious career there, designing prominent reinforced concrete buildings, selling his concrete mixers, and licensing builders to use his system, thereby spreading the use of reinforced concrete. Thaddeus Hyatt also lived a long life, but was not active in business in his later years; he died at Sandown, Isle of Wight, England. These four men helped establish reinforced concrete as a mainstream building material in the United States.

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