The History of Shotcrete Equipment

Dry-Mix Shotcrete—The First Shotcrete

By Patrick Bridger

Most of you have heard that Carl E. Akeley was credited with the invention of the first successful shotcrete machine. Akeley was employed by the Field Museum of Natural History in Chicago, IL, where, in his studio, he continued to study anatomy so that the animal skins would fit his models correctly. It was at this point in his career when he developed his most successful inventions, including improvements to the motion picture camera as well as the development of the cement gun. A common belief is that Akeley developed the cement gun to rapidly and economically build up forms by spraying cement grout onto a frame so that animal skins could be placed and stretched for his displays (Fig. 1).

This theory has never been proven, as there is no clear evidence of this being the case. A more likely scenario comes from a different story by Clarence Dewey, Akeley's assistant. In 1907, Dewey's account was that the Field Museum building was in dire need of repair and funds were limited for such aesthetic repairs. Dewey had been working with a compressed air machine, painting imitation rocks for an Akeley exhibit, when the museum director asked Dewey and Akeley if they could build a machine to spray plaster as an effective means of repairing the exterior of the building. The moment of intuition is related by Akeley in his memoirs:

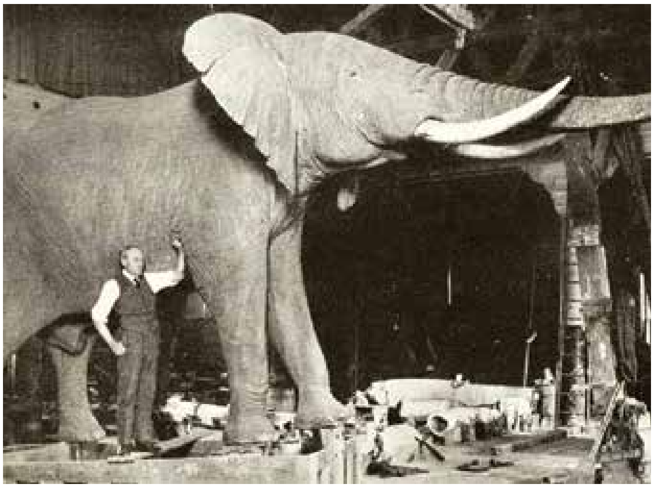


Fig. 1: Charles Akeley at Field Museum of Natural History in Chicago

"In the many experiments of one kind and another that I had tried in working out methods for mannequin making, I had among other things used a compressed air machine. It occurred to me that it would be possible to make an apparatus on this principal that would spray a very liquid concrete on to the side of a building."

Akeley realized that he did not have the expertise or finances to market the machine successfully. After approximately 3 years of attempting to generate public interest, he successfully succeeded in finding several backers. In 1911, they incorporated the General Cement Gun Product Company to manufacture the gun, and General Cement Gun Company to market the machine. Those owning stock in the General Cement Gun Company were John E. Shepherd, Robert L. McElroy, Carl E. Akeley, Charles A. Cooper, Garret D. Cooper, Wallace B. Wolf, and Worth E. Caylor. To protect the investment from possible infringement suits, they purchased the following patents: a sandblaster apparatus (773,665, and 783,218) invented by John D. Murray, and sandblaster nozzle (839,483) invented by William H. Kelly. The similarities between the Murray sandblaster and the Akeley cement gun are undeniable. Both handle a dry mixture in the hopper, both use a single hopper, and most importantly, in both, hydration occurs in the nozzle. The second Akeley patent reveals a dual-chamber machine, which allows the upper chamber to be refilled while the lower chamber is in use, thus allowing the machine to be kept in continuous use. In the prototype, the feed wheel was in a vertical position, while the second patent placed the feed wheel in the horizontal position for improved material control and to prevent clogging. The feed wheel was the most important technological development other than the nozzle. When the cement was mixed with the moist sand, the horizontal feed wheel breaks up the mixture before introducing the material into the hose. Without the feed wheel, it would be difficult to control the mixture and arrive at proper results.[1]

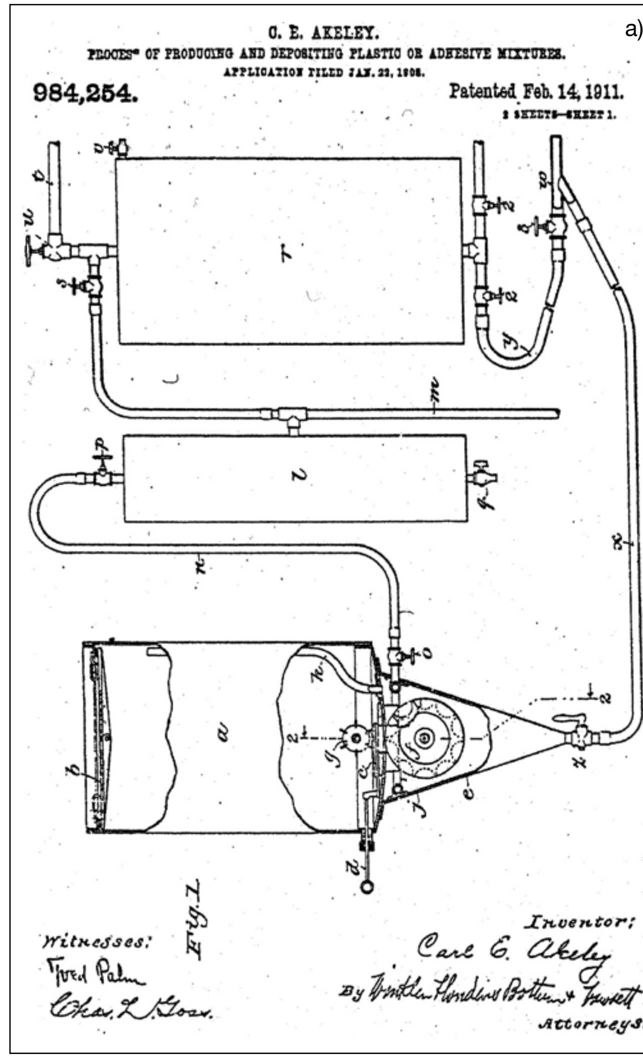
Akeley's patent (984,254) (Fig. 2(a) and (b)) relates an important discovery well:

"Hydraulic cement is more efficient as a binding agent when it is permitted to set shortly after hydration and without physical disturbance, in a position where it is intended to permanently remain. In the former process of making a

concrete, the utilization of this law was impossible from the nature of its performance, as the cement was hydrated and mechanically mixed with sand or similar material, and when mixed, the conglomerate was taken to the place of application and applied, the result being that the crystalline form of the hydrated cement was necessarily broken and hence made less effective as a binding agent. Another law is that hydraulic cement is more effective when hydration is accomplished with just the amount of water needed to supply the water of crystallization and that under proper conditions such cement will take up the exact amount of water or moisture needed for this purpose. In the operation of the former process, such conditions were impossible in the nature of the performance.

"In the operation of my process, I bring the dry cement and sand, either separately or mixed, together in the appropriate proportions to the point of delivery adjacent to the point of application. Through a separate conveyor I bring the water to the same point, and under pressure I forcibly project the three elements together against the object or structure. In carrying out my process, I prefer to unite the three elements, sand, cement, and water, in a suitable nozzle from which they are together forcibly projected against the object. I have observed that the point at which I bring about in the projecting of these elements with the cement sand and water together in the manner indicated, permit the cement to take up just enough water or moisture to effectively bring about its crystallization. The particles of cement, having taken up just the right amount of water, are violently projected against the object where they are intended to remain and set, thus these particles are immediately placed upon hydration in position where they are to remain. They are not again disturbed, and in view of the fact that they have taken upon only the sufficient water for the purpose of their hydration, they rapidly crystallize and set. The fact that the sand is also brought in contact with the water, (predampened material) wets it sufficiently to be united with cement. In other words, the individual particles of sand are moistened and consequently in a better condition to cooperate with cement forming the concrete. Furthermore, the fact that all of these elements are violently projected against the object continuously and forcibly operates to drive the particles home into the interstices of the surface presented, thus tamping the concrete as it is formed and expelling surplus water or included air that may be present, leaving the concrete hard, dense, and homogeneous."

On May 9, 1911, Patent 991,814 was issued for an "Apparatus for



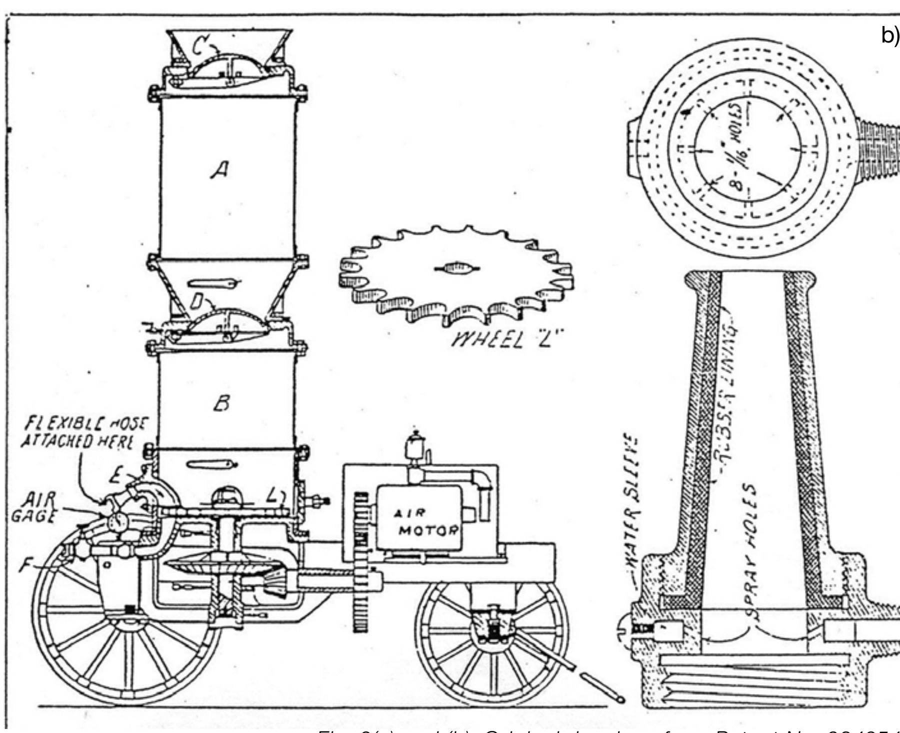


Fig. 2(a) and (b): Original drawings from Patent No. 984254 mixing and applying plastic or adhesive materials." Although Akeley's name was on the patent, is seems that others were busier in promoting the invention than he was. In December 1910, the cement gun was already exhibited at the Cement Show in New York's Madison Square Garden. At the 7th Annual Convention of the National Association of Cement Users held during the show, a paper delivered by G.L. Prentiss, Vice President of Parsons Manufacturing Company, NY, about the cement gun and its use, particularly in lining the Hunters Brook Siphon of the New York Water Supply at Yorkshire Heights, impressed the audience just as much as the machine itself. A civil engineer named S.W. Traylor was especially quick to appreciate the wide variety of uses for the cement gun. His engineering company in Allentown, PA, acquired the rights to the machine, and he soon renamed the firm the "Cement Gun Company."

The term "gunite" was coined in 1912, and the unique idea of applying cement mortar onto a surface at high velocity was an immediate success. Early projects included encasement of structural steel support elements of New York's Grand Central Station to strengthen and protect them against fire and corrosion. The density, bond characteristics, and compatibility with structural steel elements, as well as the longevity of protection, created a design and construction demand for this type of application throughout the rail and bridge industries. Water transportation and storage facilities became common gunite construction applications because of the reduced forming requirements and the superior properties of concrete placed by the pneumatic spray method.[2]

From 1911 to 1916, development of the machine and nozzles continued to progress. The original model was the model G.L. machine, but the model N-0 was soon introduced in 1914. The model N-0 was still a double-chamber machine, but the vessel geometry changed to the hourglass shape that is most recognized in Fig. 3 and 4.

The Cement Gun Company had a contracting department, but they did allow sales of machines to anyone, as shown in Fig. 5.

The cement gun was widely used in building construction, strengthening, façade repair, corrosion protection, fireproofing, furnace lining (refractory), mining, tunneling, canal lining, slope stabilization, water and wastewater tanks, and various other applications, as we still use shotcrete today. These machines were sold throughout the United States and spread to many other countries throughout the world in relatively little time once they were commercially available. (I have in my possession the original "Birth Certificate" book, which is a handwritten recording of every customer who purchased a cement gun from 1914 until the early 1970s.)

It wasn't until after WWII that technological advances were made in the continuing development of shotcrete machines. Sometime in the late 1940s, a company from Troy, MI, called NFS Industries developed the first rotary barrel type device called the "Jetcreter." Essentially, this is a rotary lock air chamber device in which the vertical rotor cylinders are continuously fed by gravity and discharged straight down to the outlet below. This proved to be a successful machine and enabled higher output for various applications. In addition to the development of the rotor machine, they also developed a highly successful volumetric continuous mixer for site mixing and feeding the rotor machine.

Hans Egger, from Meynadier AG of Switzerland, took notice of this machine and made it more compact for use in tunnel construction. In 1957, the Meyco GM-57 was introduced and soon became a popular machine in tunnel construction and other higher-output applications. Further improvements were made to the design of the clamping device within the next decade, and a smaller version called a GM-27 was introduced. Aliva is another company that further made design changes and improvements of the rotary barrel gun,

Fig. 3


Fig. 4: Model N-2, circa 1916

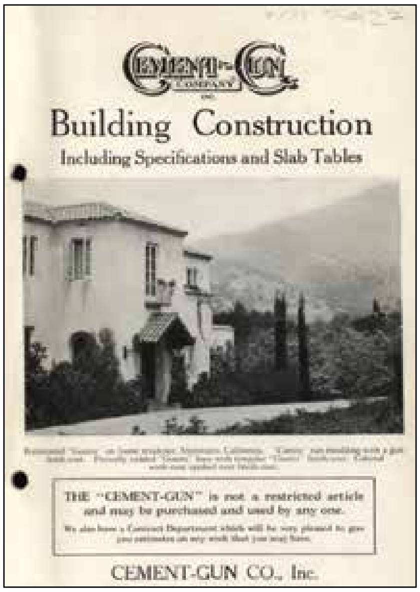


Fig. 5: Cement-Gun Company Bulletin

Fig. 6: Meyco GM-060 Rotary Machine

Fig. 7: Aliva AL-252 Rotary Machine

Fig. 8: Reed Model LOVA

which Sika acquired, further improved, and very successfully marketed worldwide in underground construction.

Today, both Meyco and Aliva brand rotary machines (refer to Fig. 6 and 7) are alive and well and available worldwide. Aliva is recognized worldwide in mining and tunneling construction as well as refractory use. The current Meyco versions are available from Normet, who acquired the Meyco dry-mix shotcrete machines within the last 5 years. There are copies of both the Aliva and Meyco brand machines, but none compare to the robustness of the original, genuine versions of the Swiss-designed and built machines.

The next dry-mix shotcrete machine development came in the 1960s by Frank Reed with the development of the rotary bowl-type shotcrete machine.

The rotary transport bowl is divided into radial compartments, is gravity fed, and is pneumatically discharged into the outlet and connected delivery hose, as illustrated in Fig. 8.

The rotary bowl gun design became very successful in a wide variety of shotcrete applications and the technology was readily accepted worldwide. Like the pressure vessel and rotary barrel design, the rotary bowl machine has also been copied by various other manufacturers. The Reed models LOVA and SOVA are popular in applications such as concrete repair, refractory, new construction, swimming pools, tunneling, mining, and various other applications.

Fig. 9: Frank Reed

Although never commercially produced, Frank Reed (Fig. 9) also patented an automatic double-chamber pressure vessel machine. Frank was quite the innovator in dry-mix shotcrete equipment.

J. F. Shea Construction used the Reed machines in the 1960s for their tunnel construction projects. Shea purchased Reed in 1970.

Once all three successful types of dry-mix shotcrete machines were established, not much changed in the technological development of dry-mix shotcrete equipment. The Cement Gun Company operated continuously from 1911 under the ownership of the Collier & Roberts family of three generations with other names of Allentown Pneumatic Gun and Allentown Pump & Gun. In 1991, Master Builders Inc. acquired Allentown and divested the company in 2004 to private ownership, which George Yoggy and myself were investors. Putzmeister acquired Allentown Equipment in 2007 and eventually closed operations down in Allentown in 2011 and moved the company to Putzmeister headquarters in Sturtevant, WI. In 2012, Putzmeister eliminated the Allentown brand and kept production of the Allentown shotcrete products under the Putzmeister brand.

References

1. Rodriguez, L., *From Elephants to Swimming Pools, Carl Akeley, Samuel W. Traylor and the Development of the Cement Gun*, Canal History and Technology Press, Easton, PA, 2006, 150 pp.

2. Yoggy, G. D., "The History of Shotcrete," *Shotcrete*, V. 7, No. 3, Summer 2005, pp. 26-32.

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