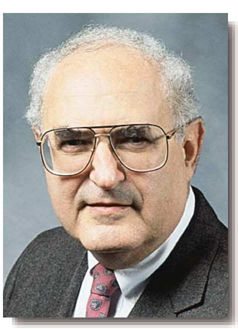
History of Exposed Aggregate (Mo-Sai) Architectural Precast Concrete



Sidney Freedman
Director Architectural Precast
Concrete Services
Precast/Prestressed Concrete Institute
Chicago, Illinois

This article presents the origins and evolution of exposed aggregate architectural precast concrete in the United States, which goes back nearly 100 years. Primary emphasis is placed on the pioneering work of Louis Falco, Sr., Dextone Company, and John Earley of the Earley Studio, the firms that gave birth to the Mo-Sai method of producing exposed aggregate architectural panels. As the industry grew in the fifties, the Mo-Sai Institute was formed in 1940. The Mo-Sai technique of production is discussed in the article and some of the significant buildings that used Mo-Sai panels are described. Special care and expertise were needed to execute the detailed instructions of the manufacturing process. It is concluded that the Mo-Sai method of fabrication had a profound influence on today's architectural precast concrete industry.

Today, exposed aggregate architectural precast concrete is a well accepted and much used material for cladding the exterior of buildings. Its widespread use is evident in both prestigious and conventional buildings across the United States and throughout the world. However, like other modern art forms, exposed aggregate architectural precast concrete has a long history going back nearly 100 years. Some excellent examples of early architectural precast concrete using the Mo-Sai method are shown in Figs. 1 to 5.

This article provides the beginnings and evolution of exposed aggregate architectural precast concrete panels, describing principally the Mo-Sai method of production. It should be mentioned that, over the years, there have been other techniques for producing architectural precast concrete, such as the Schokbeton method. However, Mo-Sai was the oldest and certainly the most influential method.

Since the turn of the 20th century, precast concrete has been used in the form of blocks, utility items and cast stone products. For the most part, the producing firms were family enterprises utilizing skilled artisans, with a feeling for the properties necessary to produce concrete in various forms and textures.

Between 1913 and 1935, this group of artisans, through the production of a quality product, created a demand for cast stone as a substitute for natural stone on building facings, sills, lintels, stairs, and architectural ornamentations. Unfortunately, the technology for this product was not fully developed. With many producers lacking both knowledge and skill, the product

Fig. 1. Blue Cross-Blue Shield Office Building, Richmond, Virginia.

Fig. 2. Blue Cross-Blue Shield Building, Boston, Massachusetts.

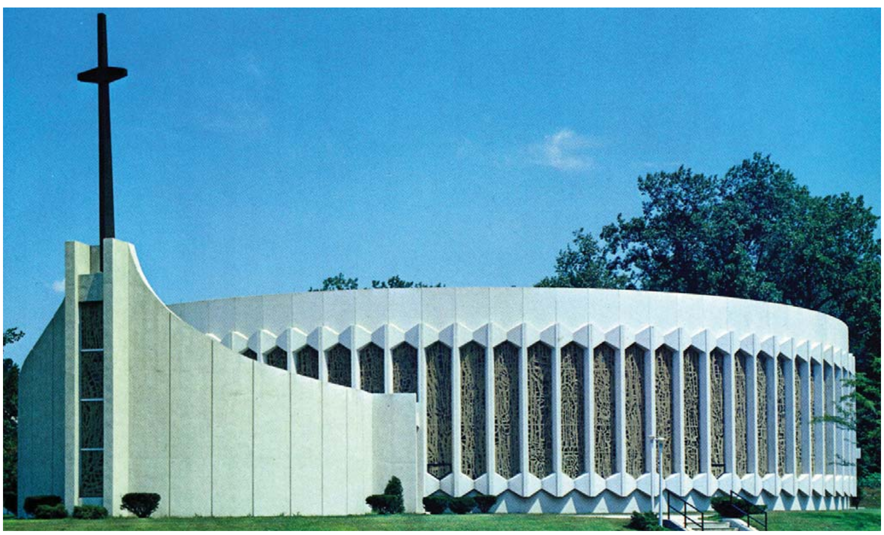


Fig. 3. Holy Rosary Church, Ansonia, Connecticut.

Fig. 4. Pet Plaza, St. Louis, Missouri.

Fig. 5. Armstrong Rubber Company Corporate Headquarters, New Haven, Connecticut.

failed to withstand the normal attrition of weather and other durability issues. As a result, during this period the industry did not progress very far.

In the late 1930s, a few architects cautiously began to use "architectural concrete slabs" for industrial and office buildings. The Earley Studio did the slabwork for these early buildings, notably the Squibb Laboratories in New Brunswick, New Jersey, and the Normandy Building in Washington, D.C., in 1938. However, John Earley and Basil Taylor (the founders of the firm) soon came to realize that the use of thin precast concrete slabs could never come into general use until more manufacturers entered the pre-

Fig. 6. John Earley and Basil Taylor at the Rosslyn Plant of the Earley Studio in Washington, D.C., circa 1935.

casting field (see Fig. 6). They had the foresight "to see the Earley Studio become a center for the training and inspiration of other craftsmen with the vision, tenacity and courage to carry on in a field whose potential seem unlimited."

Earley licensed other firms to use the "Earley Process," and brought their craftsmen into his plant for training. The licensing and training policy was so effective that thin slabs became generally available throughout the eastern United States by 1939. Indeed, some of the newly trained producers became formidable competitors of the Earley Studio.

A pivotal development of the precast concrete industry occurred in 1938 when the David W. Taylor Model Testing Basin for the U.S. Navy at Carderock, Maryland, was completed (see Figs. 7 and 8). The exterior surfaces of the shop, office and laboratory group of buildings, the fitting-out room, the turning basin building and the boiler house and substation buildings were faced with precast exposed aggregate, reinforced concrete panels, which served as the outside form against which the structural concrete was cast.

Since this type of exposed aggregate concrete was originated and developed by John Earley, he was retained as expert consultant for the work. However, the actual production of the panels for this project, totaling some 135,000 sq ft (12,500 m^2), was undertaken by the Dextone Co. of New Haven, Connecticut, a cast stone manufacturer, who had no previous experience in the production of this type of panel. Since the process was fairly complex, considerable time was required to develop facilities and to train personnel by Earley Studio before a product of acceptable quality was obtained.

In Fig. 9, the panels for the shop building are shown in place ready to receive concrete. Most of the slabs were either 8 or 10 ft (2.44 or 3.05 m) high, 8 ft (2.44 m) wide and 2 in. (51 mm) thick. Despite their unusually large surface area, even the 8 x 10 ft (2.44 x 3.05 m) panels weighed only 2000 lbs (907 kg). They were easily handled with ordinary stone-setting derricks.

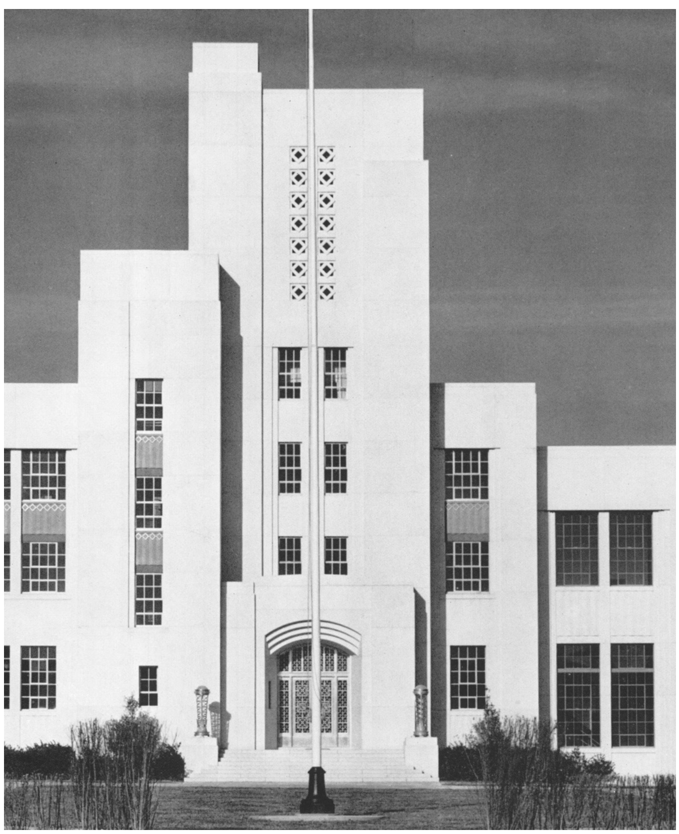


Fig. 8. The walls of the Model Basin Office Building are reinforced concrete cast against 2 in. (50 mm) forms of decorative concrete.

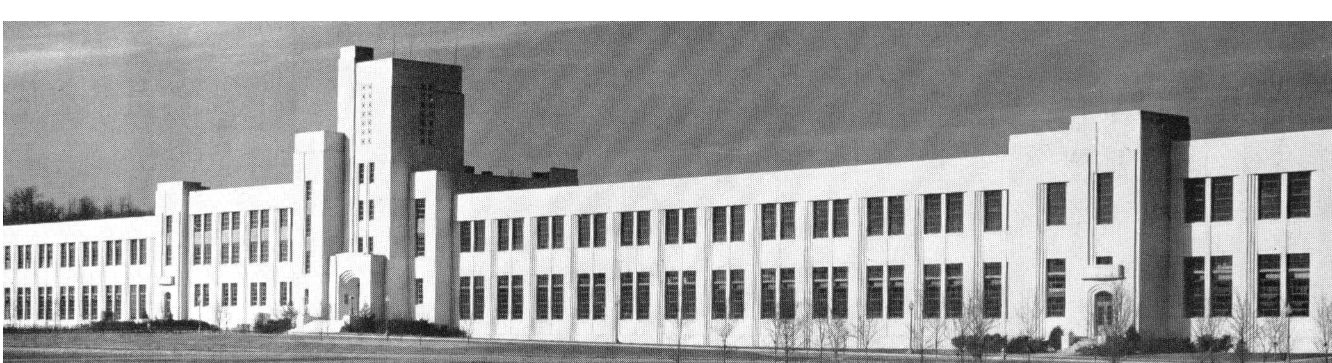


Fig. 7. The main building façade of the David W. Taylor Model Testing Basin, Carderock, Maryland, completed in 1938.

Working from the experience obtained on the Model Basin, Louis Falco, Sr. of the Dextone Company decided to make the exposed aggregate architectural panels available for industrial purposes throughout the United States. Falco filed for registration of the trademark Mo-Sai in December 1939, stating the name was in use since September 1937. Since everyone was calling Earley's work a concrete mosaic, the trade name "Mo-Sai" was a natural. In Earley's mosaics, aggregate particles were substituted for the usual tesserae (aggregates in the form of small cubes or similar geometrical shapes).

The principal organization representing precasters in those days was the Cast Stone Institute. Falco, who was a member of this group, invited seven other firms to join him in forming a new group of their own, called Mo-Sai Associates. This they did in 1940.

Besides Falco, the seven original charter members were:

- Eugene Bossi of Cambridge Cement Stone Co. in Allston, Massachusetts
- Otto Buehner of Otto Buehner & Co. in Salt Lake City, Utah
- Edward Olsen of Badger Concrete Co. in Oshkosh, Wisconsin
- Ernest Wiedemann of Economy Cast Stone Co. in Richmond, Virginia
- Paul Formigli, Sr., of Formigli Sales Co. in Philadelphia, Pennsylvania
- Mac Arnold of Arnold Cast Stone Co. in Greensboro North Carolina

The Mo-Sai Associates became the Mo-Sai Institute, Inc. in 1958.

With the proliferation of the precast/prestressed concrete industry in the 1950s and 1960s, Mo-Sai further expanded its membership base (see Fig. 10).

Disseminating the proper technical information was a major problem in those early days. Falco got around that problem by sending Herman Frauenfelder, a man schooled in the intricate techniques and details of Mo-Sai precasting, to the different member companies where he passed along this proprietary information.

A company joining Mo-Sai paid a sizable initiation fee for franchise

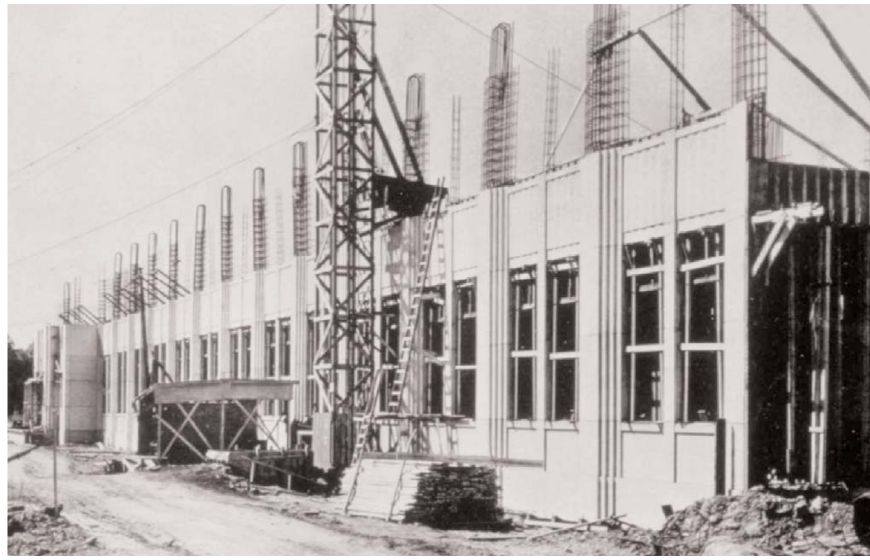


Fig. 9. Panels for Model Basin shop building are in place ready to receive concrete.

Fig. 10. Board of Directors of Mo-Sai Institute: Standing from left are: Frank Fachetti, Ernest Weidemann, Frank Dooley, Edward Olsen, Paul Buehner and John Fitch. Seated from left are President Ralph Robinson, Ted Grassi and Charles W. Wilson (circa 1965).

Fig. 11. Examples of several of the Mo-Sai marketing tools.

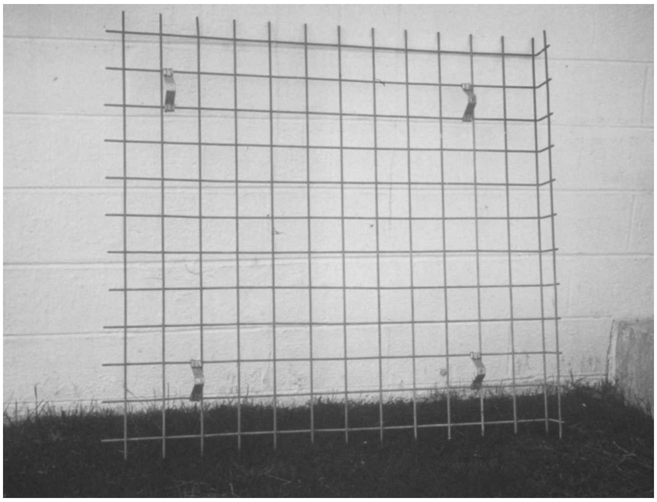


Fig. 12. A typical mesh reinforcement 4 x 4 in. (102 x 102 mm) by No. 3 x 3 wire electric welded and galvanized with Type "A" anchor clips.

Fig. 13. Worker filling in the joints of mold with molding plaster to prevent leaks. Mold is for 2 in. (50 mm) slab with 10 in. (250 mm) return.

Fig. 14. Inspector checking Mo-Sai mold for size, shape and trueness.

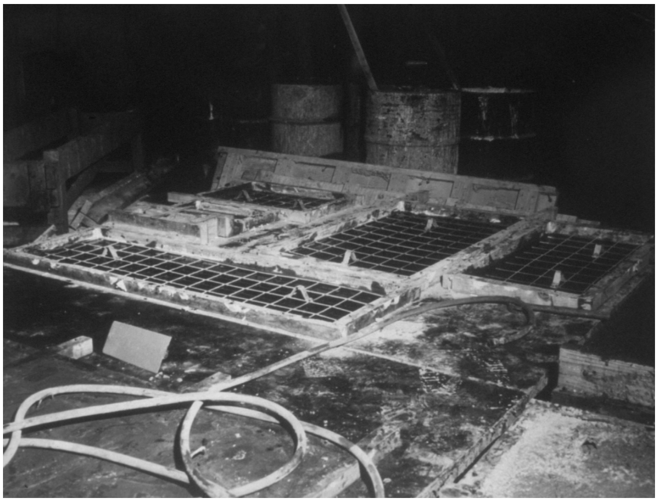


Fig. 15. Several molds with reinforcing mesh temporarily placed to check for fit.

rights to manufacture their products by the Mo-Sai process. By 1969, there were 22 Institute members in the United States, Canada and Japan. Along with the license fee came a geographic territory in which no other license would be issued for manufacture. This was not considered "restraint of trade," since there was no restriction on shipping the product into another firm's territory.

Dues were paid into the Institute based on a flat yearly fee rather than on individual production. This money was divided up in a number of ways. Some of it was used for a plant inspection program, some for advertising and promotion, some for special technical and engineering aids, some for audio-visual materials, and some to help finance the group's management and technical meetings which were held twice a year.

Except for special occasions, Institute funds were not generally used for research projects. Rather, it was the responsibility of each affiliated firm to shoulder part of this load. All such information was then shared among the members at their semi-annual technical meetings.

The biggest value accruing to membership was access to shared technical information. The license required dissemination of technical knowledge between members and forbade its disclosure to non-members. To safeguard this policy, plants were open for visits only to Mo-Sai members.

Advertising and public relations played a vital role in Mo-Sai's daily operations, which gave architectural precast concrete considerable national recognition and general acceptance within the design community (see Fig. 11). Black and white and four-color advertisements promoting Mo-Sai products appeared regularly in influential magazines such as *Architectural Record, AIA Journal, Progressive Architecture, Architect and Engineering News* and the *Producer's Council Technical Bulletin*, as well as annual eight-page inserts in *Sweet's Catalog*.

Trying to pry out information on the Mo-Sai formula was about as futile as storming the gates of Fort Knox! The

Fig. 16. Note stiffness of low water-cement ratio facing mix just discharge from mixer.

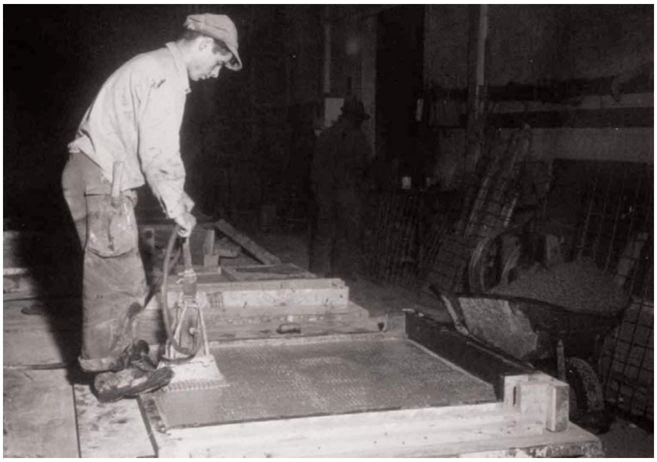


Fig. 17. Vibration of facing mix using grate vibrator.

Fig. 18. Reinforcement held in proper position on top of vibrated facing by small mounds of backing mix under the mesh.

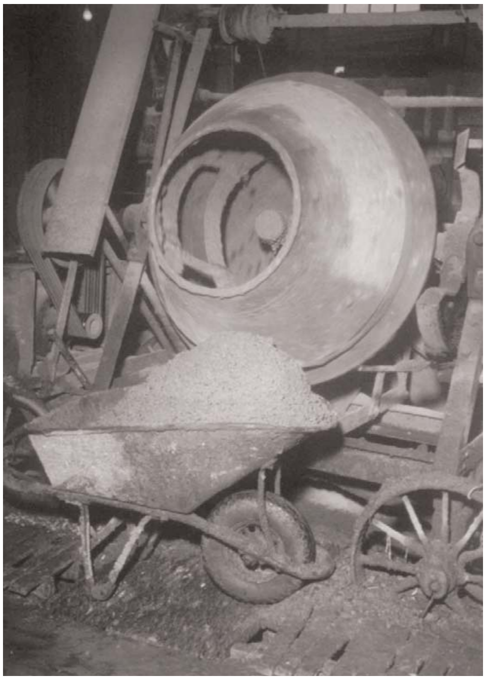


Fig. 19. A batch of backing mix just discharged from mixer.

whole operation was a carefully kept secret. Certain general facts, however, were allowed to leak out. For example:

Standard Mo-Sai panels were usually 2 in. (51 mm) thick and comparatively light, weighing approximately 25 psf (122 kg/m^2). Sizes of panels varied from 20 to 100 sq ft (2 to 9 m^2), and the thickness of the panel was increased according to steel reinforcing design requirements.

The panels were reinforced with 4 x 4 in. (102 x 102 mm), $^3/_8$ in. (9.5 mm) diameter electrically welded galvanized wire fabric. Anchor loops consisting of 1 in. wide x $^3/_{32}$ in. (25 x 2.4 mm) thick galvanized strap iron were hooked around the panel reinforcement at 2 ft (0.61 m) intervals each way, and the loop part which projected 1 in. (25 mm) clear of the concrete was punched to receive the end of a form tie bolt (see Fig. 12).

The facing and backing mix were each 1 in. (25 mm) thick. For panels $2^1/_2$ in. (63 mm) and not less than 2 in. (51 mm) in thickness, utilizing a maximum of $^5/_8$ in. (16 mm) aggregate in the facing, Mo-Sai required a minimum compressive strength of 7500 psi (52 MPa) at 28 days of age when tested by appropriately sized cubes cast from the same materials.

Where a Mo-Sai facing mix was used involving larger than $^5/_8$ in. (16 mm) facing aggregate in panels over $2^1/_2$ in. (63 mm) thick, or where special designs and shapes involved sculptured patterns such that the sections had to be cast principally of Mo-Sai facing mix, the compressive strength was required to be not less than 5500 psi (38 MPa). Finished units had an absorption of less than 5 percent.

Molds were typically constructed of wood, shellacked and then lined with masonite, similar to Earley's process. The masonite lining was given two coats of shellac, then coated with a solution consisting of one-third castor oil and two-thirds shellac. Shown in Fig. 13 is a mold for a 2 in. (51 mm) thick Mo-Sai panel with a 10 in. (254 mm) return. In this photo, the workman is filling in the joints of the form with

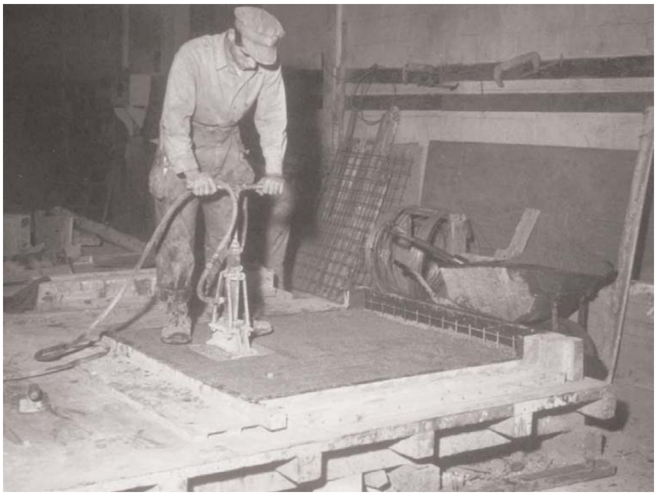


Fig. 20. The backing mix being vibrated into place.


Fig. 21. Vibration of slab in its final stages. Top of side forms are being vibrated to help mix go into place at slab ends.


Fig. 22. Stripping the panel from the mold with excelsior filled sack to protect edges from chipping.


Fig. 23. Face is wire brushed to expose aggregate.

molding plaster to prevent leaks.

Before casting, the forms were greased with a mixture consisting of 1 gallon (3.8 L) of animal fat (tallow or lard oil) to 5 lbs (2.3 kg) ground soapstone to prevent sticking of the casting to the mold. With this treatment, forms could be reused approximately 60 times before relining was required. After the particular form had been built, it was coated with a retarder to keep a thin outer layer of cement from setting up.

The exact chemical composition of the surface retarder used was a closely held secret, as was all technical information developed by the individual members. In Fig. 14, an inspector is shown checking a mold for size, shape and trueness. In Fig. 15, reinforcing mesh is temporarily placed in molds to check for proper fit.

A batch of facing mix is shown (in Fig. 16) just discharged from the mixer. Note the stiffness of the mix. After the facing mix is placed and vibrated with a flat grate, high frequency vibrator, the reinforcement is placed in position on top of the vibrated facing, not less than $^3/_4$ in. (19 mm) back of the face of the panel (see Fig. 17).

The reinforcing mesh is held in its proper position, that is, in the middle thickness of the slab, by small mounds of backing mix under the mesh (see Fig. 18). It was important to keep mesh in its proper position to prevent corrosion of the steel. Next, a batch of backing mix is shown in Fig. 19 just discharged from the mixer. Note that this mix is less stiff than the facing mix. The backing mix is then placed and vibrated (see Fig. 20).

In Fig. 21, a workman is shown vibrating the slab in its final stages. Note that the top of the side form is receiving vibration. This is done to help the mix go into place at the slab ends. Returns being cast in a vertical position were vibrated internally with a $^1/_2$ in. (13 mm) diameter rod pushed into the concrete.

The panels are removed from the molds before the surface is thoroughly hardened, usually within 12 to 24 hours depending on the air temperature; usually, 12 to 24 hours for 80°F (27°C) and 18 to 24 hours for 50°F (10°C). Note that the lower temperature is preferable so as to avoid exces-

Fig. 24. After panel is brushed, it is "smeared in" to fill in holes and imperfections.

Fig. 25. Mo-Sai panels being loaded on truck which has wooden A frame easels.

sive shrinkage resulting in hairline cracks.

In Fig. 22, a typical panel is shown being lifted from the mold. Note the excelsior filled sacks for protection of panel edges. Also note the marked casting date "11/2," the job number "J329" and piece number "#4." Lifting is done slowly without jerking as the panels are less than 18 hours old.

As soon as a panel is removed from the mold, it is stacked in a vertical position on a traveling easel and gone over with an electrically driven belt sander to remove excess mortar on the face. Then, the panel is wire brushed to remove the surface mortar and expose the aggregates in their true colors (see Fig. 23). Each panel is then checked for size, trueness, broken edges, sand pockets, and repaired, if necessary. Repairs are made within 36 hours of casting.

The panels are initially cured for 3 days, being thoroughly sprayed with water twice a day. On the third day, a solution of one part of hydrochloric acid to five parts of water is applied and then brushed off using plenty of water. The proper degree of acid etching for uniform texture is then checked under a strong light.

In addition, at the end of this curing period, the panels are given a preliminary cleaning and are subjected to a "smearing" operation to fill in small occasional voids, which occur in spite of the most careful casting (see Fig. 24). Then, surface treating and hardening chemicals are incorporated on the face. At the time, Mo-Sai had an operations manual with complete instructions covering brushing out and smearing in.

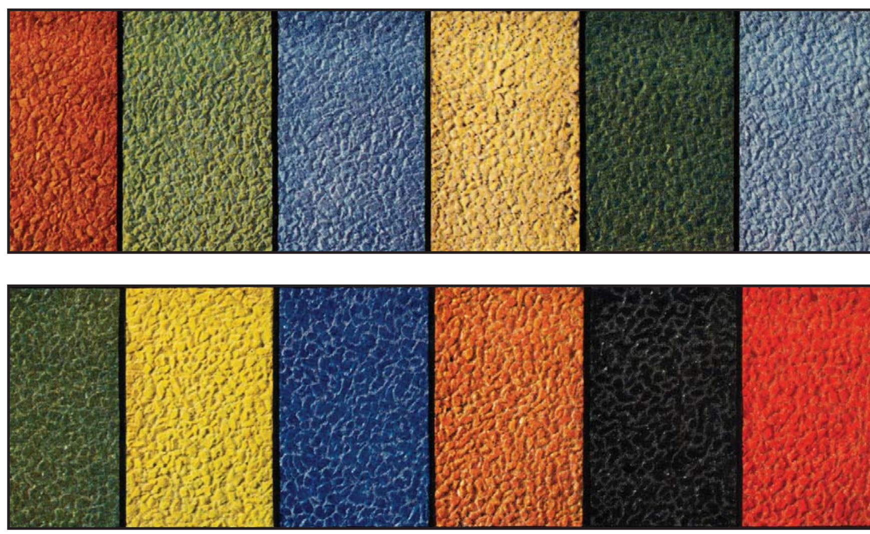


Fig. 26. Six of the eight colors of manufactured ceramic aggregate adopted as standard (top). A group of colored aggregate concrete panels showing six of the colors of manufactured vitreous aggregate adopted as standard (bottom).

Next, the slabs are subjected to further curing for four more days, wetting them twice daily. On the seventh day, they are given a final light acid wash of one part hydrochloric acid to seven parts water, except for spots that might need a stronger application to bring them to the texture of the sample. The panels are then ready for shipment. In Fig. 25, Mo-Sai panels are shown being loaded on a trailer truck. The panels are stored both in the yard and on the truck on wooden easels.

The mixes which made up the panels were unique. For aggregates used by Mo-Sai Associates, the Dextone Co. at Redding, Connecticut, had the only crushing and grading facilities in the United States which were devoted exclusively to the production of aggregates for architectural precast concrete panels. The aggregates used in most Mo-Sai projects had a hardness of about 7 on Moh's scale, approximately that of carbon steel.

Colored granite, quartz, ceramic or porcelain vitreous from all over the world were crushed and graded to the proper sizes to produce the facing portion of the panels. The crushing methods gave a cubical shape, by using a

Fig. 27. Dixwell Playhouse, Hamden, Connecticut used Mo-Sai panels as veneer for masonry construction.

Fig. 28. Mo-Sai panels were used as veneer on masonry construction for this project in New Haven, Connecticut.

Fig. 29. Panels were also used as veneer on the Wilcox Building in Meriden, Connecticut.

hammer mill as the final crusher.

Rounded or cubical particles not only assisted in obtaining a dense, uniform texture but their shape ensured maximum embedment. The fines or sand also were from the same crushed materials. The sand was very clean and free of dust, as the dust might act as a pigment.

Ceramic aggregate was made from high grade clays and other ceramic raw material by processes similar to those used in producing pottery and china ware (see Fig. 26, top). The vitreous aggregates were made with materials and by methods similar to those used in producing porcelain frits or glass (see Fig. 26, bottom). While the colors of ceramic aggregate are bright and clear, they are characteristically soft in color. Vitreous aggregates are distinguished by their greater luster and brilliance than the ceramic aggregates. Certain colors could only be produced in the vitreous type of aggregate.

The strength of color in concrete made with colored aggregate depends largely upon the extent to which the exposed surface is composed of aggregate particles. A coverage of 80 percent is about the minimum which gives satisfactory results. Mo-Sai mixes obtained a minimum of 85 percent.

A grading in which particles of one size predominate, with intermediate sizes between the coarser and the finer material left out entirely, produces a maximum density of aggregate on the surface. This principle of "step" or gap grading was established in experiments conducted by Professor Robert H. McNeilly, as described in *Engineering New-Record*, November 27, 1915, and has since become the basis of this type of exposed aggregate work.

Earley studied all the literature and in 1921 patented the idea of using step or gap- graded aggregate to achieve uniformity and color control for exposed aggregate concrete. This was an important contribution to the development of architectural precast concrete, since uniformity in the distribution of the aggregate in the surface and in its exposure helps to prevent an uneven appearance.

Average mix proportions for Mo-Sai and Earley panels were approximately one part fines to four to seven parts of two or more sizes of coarse material. The aggregate-cement ratio was approximately four parts to one while the water-cement ratio in a very damp mix was as great as 0.53, or 6 gallons (23 L) per sack of white or grey cement. The only exception was for returns where the water-cement ratio was reduced slightly to prevent sand pockets.

In many cases, color pigment was incorporated in mixes with colored aggregate to minimize the color differential between the matrix and coarse aggregate. Backup mixes were composed of 90 lbs (41 kg) of washed and screened concrete sand plus 306 lbs (139 kg) of crushed stone and were placed integrally with the face material. Once cast, the entire plastic mass of the panel was pneumatically vibrated a second time to ensure compaction of the material and draw to the exposed back face any excess moisture. This was immediately evacuated by mechanical means and with hygroscopic materials.

The choice of texture and hence the size of the aggregate for a particular job depended upon the nature of the work itself and the distance from which it would ordinarily be viewed. From a distance of 15 to 20 ft (4.57 to 6.1 m), a surface made up of aggregate particles $^3/_8$ in. (9.5 mm) in diameter and brushed out $^1/_8$ to $^3/_{16}$ in. (3 to 5 mm) will appear smooth. For work to be seen at close range or which has a pattern in small detail, aggregate as small as $^1/_{16}$ in. (1.6 mm) in diameter may be used or the brushing may be much lighter with only the thin outer coating of cement being removed.

It was found that the larger sized particles gave a greater percentage of aggregate showing in the finished surface, and, therefore, greater intensity of color. Even for ornamentation in relief, a fairly coarse aggregate might be used and exposed by brushing without damage to moderately fine detail. In no event was the depth of the brushing greater than one-half the diameter of the predominating particles.

The execution of designs and patterns in color in concrete required a

Fig. 30. The Wilcox Building in Meriden, Connecticut.

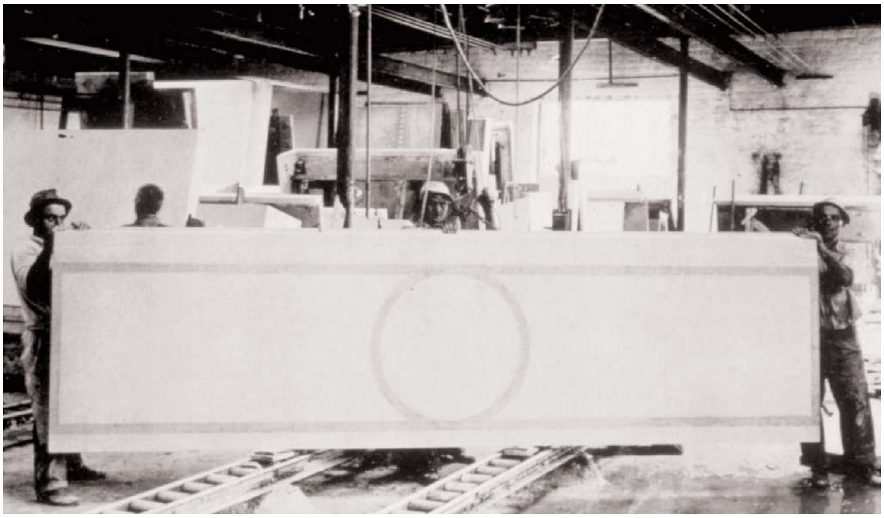


Fig. 31. The spandrel panel illustrates the detail and design possibilities.

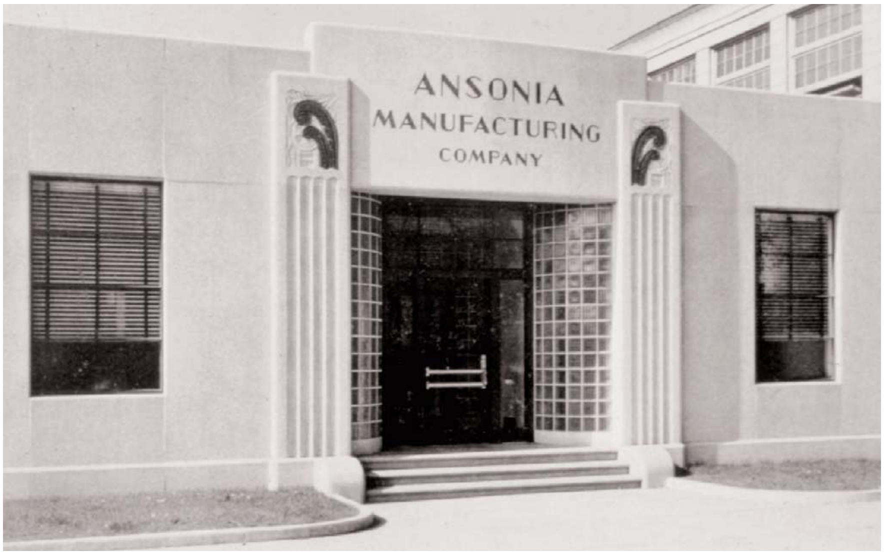


Fig. 32. The panels for this project in Ansonia, Connecticut, used precast panels as facing for cast-in-place concrete.

means of preventing the mixtures from intermingling while they were being placed in the mold. On flat work or panels this operation was accomplished by:

- Using metal stripping such as is used in terrazzo.
- Using thin strips of wood or composition which are subsequently removed and the groove pointed with a colored mortar.
- Using small ribs or fins on the face of plaster molds which leave a small V-depression between adjacent areas of color.
- Molding recesses in the face of the concrete and afterwards inlaying the various colored mixtures. On work carrying relief, the depressions of the mold itself provided separation for the colors.

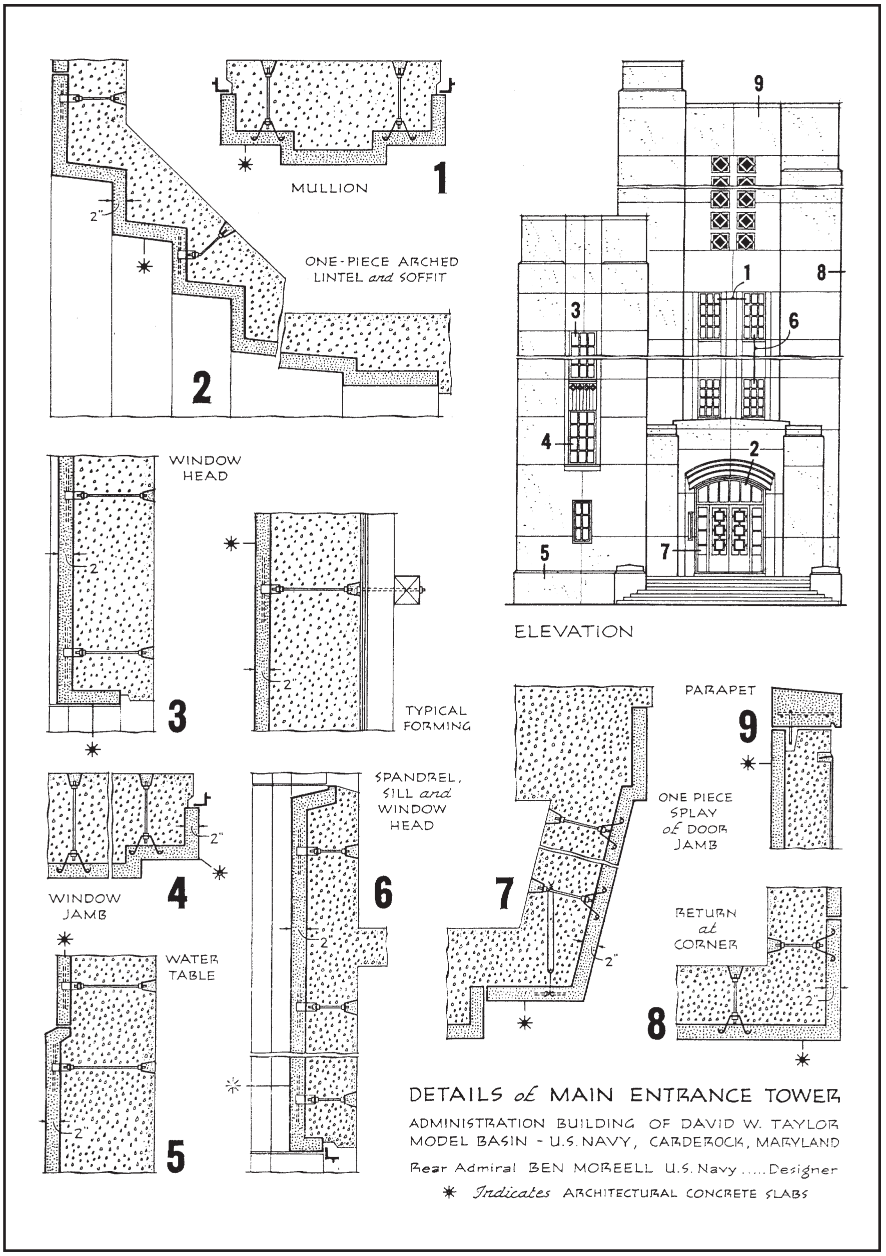


Fig. 33. Architectural panels on the main entrance tower of the David W. Taylor Model Basin, served as forms for the cast-in-place concrete. Returns were cast integrally with the facing.

Mo-Sai panels by the Dextone Co. were initially used as veneer for masonry construction or as a form and facing for cast-in-place concrete work. Examples of veneer projects by Dextone were the Dixwell Playhouse in Hamden, Connecticut (see Fig. 27); the Wire Rope Corporation of America Building in New Haven (see Fig. 28), and the Wilcox Building in Meriden, Connecticut (see Fig. 29). The name panel, 10 ft 6 in. (3.2 m) long x 5 ft 4 in. high (1.62 m), shows considerable detail (see Fig. 30) while the spandrel illustrates additional design possibilities (see Fig. 31).

Ansonia Manufacturing Co., Ansonia, Connecticut, was faced with architectural concrete panels (see Fig. 32). A single panel, 14 ft 6 in. (4.4 m) long x 6 ft $1^1/_2$ in. high (1.87 m), was used as the exterior and bottom form for the structural lintel. The company name and the design at the top of each fluted column are of black aggregate and were cast into the panels during fabrication.

As shown on the drawings, the architectural precast concrete panels on the main entrance tower of the David Taylor Model Basin served as forms for the structural concrete, eliminating the necessity for outer forms (see Fig. 33).

The Merritt and Wilbur Cross Parkways in Connecticut offer many illustrations of concrete cast against panels of exposed aggregate architectural concrete as well as the durability and flexibility of this type of material.

Among the numerous Mo-Sai installations on the parkways is the Clinton Avenue Bridge on the Merritt Parkway, near Westport, Connecticut (see Fig. 34). The abutments of this bridge are faced with architectural panels, which also were used as outer forms. Certain panels are slightly depressed and are made with red vitreous aggregate of high refracting quality (see inset, Fig. 34).

CLOSING REMARKS

The creation of quality exposed aggregate architectural components is both an art and a science. For over four decades, Mo-Sai Institute members pooled their technical expertise and craftsmanship to produce a product whose singular beauty and quality enhanced the value of outstanding buildings worldwide.

The Mo-Sai members were not only pioneer producers, but industry leaders and innovators. Unfortunately, they were so preoccupied in keeping information within their own organization that they failed to see that the mainstream precast concrete industry had acquired similar knowledge and techniques.

Mo-Sai faded out of the picture in the mid-1980s; but the sharing of information by Earley Studio laid the foundation for the growth of the architectural precast concrete industry that we enjoy today!

ACKNOWLEDGMENT

Production photographs are published through the courtesy of Economy Cast Stone Co., Richmond, Virginia [loaned by E. P. (Pete) Wiedemann].

Fig. 34. Clinton Avenue Bridge on the Merritt Parkway, near Westport, Connecticut, where the Mo-Sai panels served as formwork. Areas of the panels on the abutments are depressed and incorporate red vitreous aggregates (see inset).

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