MATERIALS/PROPORTIONING/MIXING/CURING

In the manufacture of concrete units the three important materials used are cement, aggregates and water. Constant care in the proper selection and gradation of the aggregate, assurance that the cement meets or exceeds standard specifications and a supply of clean, pure mixing water are absolutely essential to the economical production of units of uniformly high quality.

CEMENT: Three types of cement are in general demand for concrete products. They are types I, II, and III of Federal and A.S.T.M. Specifications.

Type I, or ordinary cement, is used where extended curing periods are no handicap, or where blocks can be yarded for 7 to 28 days, allowing time for the blocks to attain specification strength. Different brands may vary somewhat in color, ranging from yellowish to slate gray, and may affect slightly the color of the finished products when various brands are used. The color of two dry cements can be compared by placing small quantities of each close together and pressing a piece of glass down over them so they run together. Small differences in color will be quite noticeable at the line of contact. Of equal importance to the color conscious producer are changes in the amount of extremely fine material in the aggregates and changes in the processing.

Type II cement is generally darker than Type I. It is therefore preferred in some localities where darker units are more popular. It may set and harden somewhat slower than Type I.

Type III (high early strength) cement is being used more and more for concrete products. This cement is ground to greater fineness and produces a paste of greater coating capacity. The mix is reported to be able to carry more water, and responds more under vibration or compaction, forming denser units. This cement hardens rapidly so normal curing and storage periods are reduced and units are ready for marketing sooner. Some plants use this type of cement exclusively, finding that the small extra cost is offset by the advantages it offers.

Air entraining cements are available in all three types and their use is constantly increasing. However, additional air entraining agents may be needed at the mixer in order to obtain maximum consolidation and optimum results. This is particularly true where lightweight aggregates are being used.

AGGREGATES: The aggregates used will consist of sand, gravel, crushed stone, slag, cinders or other inert materials or combinations of them. They must be free from excessive amounts of dust, soft or flaky particles or shale, or other deleterious, materials. All the aggregates should be free from frost or lumps of frozen materials. Where stationary aggregate bins are provided, a coil of steam pipes should be arranged around the outlet of the bin to thaw out frozen lumps. This heating' will' also aid in the early hardening of the concrete in cold weather.

Aggregates are usually classified by an arbitrary division of "fine" and "coarse". In general practice the #4 screen is taken as the line of demarcation between the coarse and the fine material. The maximum and minimum sizes of aggregate used will be governed by the process of manufacture, the desired surface effects and the type and dimensions of the manufactured unit. The importance of fineness and gradation makes it obvious that the use of "pit-run" or "crusher-run" materials undesirable, since in the handling of such aggregates a segregation of sizes always occurs, and the proper proportions of "fine" to "coarse" will be impossible to control.

FINE AGGREGATES: Natural sand is the most widely used fine aggregate, although crushed granite, limestone, traprock, marble, cinders, and the patented lightweight materials are equally suitable. The material which will pass a #4 screen and leave at least 15% retained on a #8 screen is usually considered to be fine aggregate. While excessive quantities of extremely fine sand are undesirable, 10 - 20% of material passing the #50 screen increases the density of the concrete and results in a smoother block than when there is a deficiency of extreme fines.

(NOTE: Sharpness, once prominently stressed in concrete-sand specifications, is no longer considered essential.)

The weight per cubic foot of dry sand will necessarily vary with the limiting sizes, but an approximate value can be taken as 110 pounds. The specific gravity of typical river sands is about 2 .65 and the void space is 30 - 40% of the dry-packed volume.

The amount of moisture contained in the sand is important since it bulks when damp and then weighs less per cubic foot than dry sand. In proportioning mixes this has an important effect on the resulting concrete and the sand should be dry if volume measurements are used, or the amount of moisture should be determined and corrections made for it. If this is not considered, a mixture richer than necessary may result.

Small amounts of silt, clay or loam may not be objectionable, provided they do not contain organic matter, in rich concrete mixtures, where the cement supplies sufficient fine material, silt introduced with sand will result in a loss of strength. In a lean mixture, deficient in fine material, small amounts of silt may aid the strength. Sand which has not more than 10% of silt by weight is usually safe for use in the making of concrete units. In all fine aggregate there should be no coating of the grains to prevent adhesion of cement.

COARSE AGGREGATE: Coarse aggregate should be considered as that material retained on a #4 screen, and its maximum size will be limited by the dimensions of the unit to be molded. The largest pieces should not exceed one-third the thickness of the thinnest web of the units.

Gravel, since it occurs widely, is largely used. It must, of course, be clean and durable and free from soft, flat or elongated pieces and should be evenly graded from the minimum to the maximum sizes. Some tolerance is usually allowed and 15% passing the #4 sieve will usually not be objectionable.

Crushed stone is an excellent coarse aggregate, although slate and shales are not recommended and some forms of sedimentary rocks may be lacking in durability. Density is an important requirement; soft and easily-abraded stone is to be avoided. It is also very important that the stone be free from dust, and washed material should be obtained if possible. Tolerances the same as those in the case of gravel are allowable.

Blast furnace slag affords an economical source of coarse aggregate in the vicinity of steel plants. For ordinary purposes the hard, dense "air-cooled" slag which has been crushed is used, although patented processes are now being employed to produce a porous, lightweight aggregate from slag.

LIGHTWEIGHT AGGREGATES: A lightweight concrete usually is defined as one weighing approximately 100 lbs., or less per cubic foot. Some of the concrete made from the lightest aggregates, such as expanded perlite or exfoliated vermiculite, can of course be made very much lighter than this but at sacrifice of strength. The principal properties required of lightweight concrete are:

1. Lightweight itself which reduces dead loads.
2. High thermal and acoustical insulation.
3. High fire resistance.
4. Good nail-ability without cracking.

Other substantial properties are:

5. Substantial compressive and flexural strength.
6. Low water absorption.
7. Resistance to repeated freezing and thawing.
8. Low drying shrinkage and thermal changes.
9. Chemical inertness.
10. Good bond with reinforcing steel.
11. Good elastic properties

Many of the properties of the concrete are determined by the type of aggregate used, but optimum results can be obtained by careful selection of the proper grades of aggregate, the pre-treatment given (such as pre-saturation with water) and the proportioning and mixing of the aggregate and cement. Control of mixing water and the use of air-entraining agents and special mixing techniques sometimes overcome aggregate deficiencies. Air entrainment in lightweight concretes has been proven meritorious, as in ordinary concretes. Increased durability or resistance to alternate freezing and thawing is improved by the air-entrainment technique.

The raw materials commonly used can be placed in three general groups as follows:

(1) Natural aggregates, typified by pumice or bubbly lava that is taken from volcanic deposits and merely crushed, sized, and graded.

(2) The coal cinders, fly-ash or metallurgical slags obtained as by-products. Cinders are taken as is, and the others only slightly treated to be acceptable.

(3) The process materials that are given specific heat and furnace treatments to produce the expanded or bloated lightweight aggregate characteristics.

Volcanic tuffs or lava, in the form of pumice, is the light-colored porous siliceous glassy rock resulting from certain volcanic action. Its light weight and hence its value for use as a lightweight aggregate arises from the numerous cells formed by water vapor or gases evolved from the fused magma and frozen in during the cooling of the molten lava. While generally used without further heat treatment by simply digging out the mass of pumice and subjecting it to crushing and sizing. In some instances the crushed pumice is heated to incipient fusion or vitrification to increase the compressive strength. This can usually be accomplished by a slight surface fusion to seal holes and with only a small increase in the bulk density.

The aggregates most extensively used domestically and probably because of their general availability and relatively low costs, are ordinary cinders from coal-burning furnaces using coal principally in lump form and foamed or expanded slag's from blast-furnace and other metallurgical operations.

The usual method for expanding the molten slag from blast furnaces is to apply a blast of high-pressure air to steam to the stream of slag as it issues from the furnace or to pour the slag into a pit partly filled with water so that the steam resulting from the contact of the molten slag and water generates enough force to blow the slag into porous masses that can be crushed and screened to provide the desired sizes.

Perlite is a volcanic glass similar in composition to obsidian and pitchstone but characterized by its distinctive pearly luster and having 2-5% of combined water which is not expelled by simple drying but is released at the softening temperature of the rock to effect a marked expansion. The product is a white, fragile mass of macro and microscopic bubbles that gives a product weighing 3 to 40 Ibs. per cubic foot, depending on the perlite used. Mainly the super-light perlites have been developed. Because of their unusually low bulk density, excellent heat and sound insulation results when used as a loose fill or when bonded into a panel or other shape by cement or thermosetting adhesives.

Vermiculite is a hydrated magnesium aluminum silicate formed by alteration of biotite and phlogopite micas. It retains the characteristic appearance and cleavage of the micas and consists of soft pliable, inelastic lamellae. The outstanding characteristic of vermiculite is its extraordinary expansion or exfoliation on heating, with volume increases as high as 30 times its original size. As with perlite exfoliated vermiculite is sometimes used as a lightweight concrete aggregate but is better adapted to many other applications in acoustical plasters and heat and sound-insulating applications. Both expanded perlite and exfoliated vermiculite yield extremely light concretes, which can be used where strength is of secondary importance.

Clays and shales, which generally consist of the secondary or residual minerals from decomposition of igneous rocks and slates containing alterations and metamorphosed mineral constituents, are wide-spread and are available to .some extent in virtually all regions. These materials appear to offer the best potential sources for producing lightweight aggregates. Simple crushing to small lumps and the use of rotary kilns where sudden heating is applied in a restricted zone immediately before discharge is the preferred present commercial practice.

Most lightweight aggregates appear on the market under specific trade names, frequently only partly descriptive of their composition or properties. The products rrra.de from volcanic foams, chiefly pumice, which with one or two exceptions have not been thermally treated, are variously designated as: Basaltic Pumice, California Red Pumice. Insulpum Agite, Ingham Brand Pumice, Pumastone, Pumicrete, Pyramid Pumice, Volcanic Cinder and Voclaite.

Aggregates made from expanded perlite are marketed under such names as: Agite, Peralex, Permalite, Perlite, Tyolex and Superlite. Vermiculite in exfoliated forms and various grades is sold as: Alexite, Bee Tree Brand, Unicon Verco and Zonolite.

By-product processed slags include the lightweight aggregates: Celocrete Foamed Slag, Pottsco, Rockwood Slag, Slaglite, Superock, Tufflite and Waylite. Expanded natural or metamorphased clays and shales are produced and sold under the names of: Featherlite, Haydite, Lelite, Rocklite, and Solite. It is obvious that the lightweight characteristic of most of the products is reflected in the trade names chosen.

WATER: The mixing water should be free from injurious amounts of oils, acids, strong alkalies, organic matter or factory wastes. Water that is fit to drink is usually satisfactory. The water is used not only to make the mixture plastic and easy to mold, but is essential in the hydration of the cement. Any impurities present may seriously lower the strength of the concrete units and may cause undesirable acceleration or retardation of the setting time of the cement. It should not be colder than 60^0 F. since temperatures much lower than this tend to retard the setting time and early hardening of the block and, unless it is clean, stains on the finished units may result.

ADMIXTURES: Great progress has been made in recent years in the development of chemical admixtures for concrete. These are designed to increase resistance to water and to freezing and thawing, and to improve curing characteristics. Finely ground sand, hydrated lime, kaolin and diatomaceous earth are some of the general materials used to increase workability and to improve the density of concrete. In lean or harsh mixtures they measurably improve plasticity. Acting as inert void fillers, they make up for a deficiency of finely sized material. Such materials should never be used as substitutes for cements, but as additions, limited to 3 - 8% by weight of the cement. Flake calcium chloride is often used as an integral accelerator, for early strength, in amounts which may vary from as little as one pound per bag of cement at 90^0 F., to as much as four pounds per bag of cement in the lower temperature ranges. It makes possible the production of stronger blocks at lower costs by reducing the curing time and storage period required to meet strength specifications, with a consequent reduction in the amount of chipping and breakage in handling.

Calcium Chloride is used both in the dry form and in solution. In the dry form it should be added to the aggregates rather than to the cement. In solution it should be introduced with the mixing water with, of course, a corresponding reduction in the amount of water. The solution is usually made by dissolving 100 Ibs. of flake calcium chloride in 15 gallons of water, and then diluting with water to make 25 gallons of solution. This solution is especially convenient because it contains exactly one pound of calcium chloride per quart.

The recommended additions per bag of cement for various temperatures are as follows: above 90^0 F., 1 pound; 80 to 90^0 F., 1-1/2 pounds; 32 to 80^0 F., 2 pounds; below 32^0 F., 3 to 4 pounds. Additions in excess of 2 pounds (or 2 quarts of solution) are' not recommended, and may prove actually harmful by causing flash setting and a decrease in strength of the concrete.

The use of calcium chloride adds about 1/10 of a cent to the cost of a standard block. Some producers report savings in steam-curing fuel costs considerably in excess of this amount. Other benefits include improved appearance, sharper edges and greater resistance to breakage.

There has been considerable interest in the concrete units industry in air-entrained concretes because of their greater workability. This has been accomplished by the use of some type of air-entraining cement, or by the use of regular Portland cement and adding the air-entraining agent directly to the mix. This latter method has been found to give more flexibility, since varying quantities of the air-entraining agent must be used to obtain maximum benefits.

In the block industry, an air-entraining agent is used to improve surface texture, reduce absorption, and to reduce green breakage and culls, which ordinarily would result with adverse changes in aggregate gradation. Because of' the nature of the block mix, best results are attained with the use of a larger quantity of the agent than would be present in air-entraining cement. The optimum quantity is determined by actual performance and is dependent on the type of aggregates, type and condition of equipment, and other factors. Only by being able to adjust the quantity of the air-entraining agent can the maximum benefit be obtained.

In the case of cast stone, actual operation has shown that the use of an air-entraining agent will: (l) plasticize the mix and thus facilitate complete filling of the sand mold for perfect reproduction of pattern, (2) reduce bleeding and segregation, and (3) improve the durability of the finished product. These improvements can be accomplished with little or no loss of strength. As in paving concrete, the optimum air content seems to be between 3 and 5%. Because of the wetness of the cast-stone mix and the large proportion of fines in the aggregate, the amount of an air- entraining agent required is very much less than in paving concrete. By adding the agent as a separate ingredient, it is possible to control the air content in the cast-stone mix, varying the quantity as required for different types of aggregate, such as glacial sand and crushed marble, as well as compensating for changes in these aggregates.

Concrete cribbing and concrete curbing are two products which are sometimes exposed to especially severe conditions of frost action. Air-entraining agents are now being used to advantage in these products to increase resistance to weathering. The effectiveness of the treatment is indicated by the results of freezing and thawing tests conducted on specimens cut from concrete cribs made with and without the air-entraining agent. A section cut from a crib made without the air-entraining agent disintegrated completely after ten cycles of freezing and thawing in a calcium chloride solution, whereas a similar section from a crib made with an air-entrained concrete showed only very slight spalling after 45 cycles. The two concretes were directly comparable in cement content, consistency and strength. In addition, the increased plasticity of the treated concrete makes it possible to get a better finish on the units. The overall result is a quality product.

In casting concrete products made with lightweight aggregate, air-entraining agents have been used to bring about beneficial effects on both production and product. The lightweight aggregates by its ragged irregular shape is inherently harsh so that placing and finishing present real problems. By using a quantity of the air-entraining agent, nearly double the amount used in the average concrete, the mortar matrix is sufficiently plasticized to carry the harsh, lightweight aggregate, thus reducing segregation and improving placing and finishing.

In addition to the many brands of air-entraining cement now on the market, several chemical plasticizers are being manufactured to produce the same effects by addition at the mixer. With plasticizers of this type the user may control the amount of air entrained in the concrete, and avoid the risk of incurring excessive strength loss. One such plasticizer is C-202 manufactured by the Wyandotte Chemicals Corporation and exclusively distributed by Columbia Machine and their representatives. The material is sold in a granular form ready to use. For sand block the manufacturer recommends the use of 1 to 2 ounces of C-202 per sack of cement to obtain the optimum results.

Of the many plasticizers available today Alkylarylsulfonates have been termed the most popular and definitely the "work horse of the block industry". C-202 is of the Alkylarylsulfonates type, a synthetic wetting agent produced for us by one of the largest chemical firms in the world under rigid manufacturing specifications which insure the user a minimum of 40% active agent.

While C-202 is of the same general chemical type as several other leading wetting agents it has the property of being more rapidly and more highly soluble. In other words, C-202 goes to work in your mixer immediately and does its job thoroughly. These characteristics guarantee a free flow through the material and improve the speed and performance of our plasticizer.

If you are one of the producers who have not used a high quality plasticizer, and haven't seen the benefits derived in your own plant, may we suggest you purchase a barrel for trial. If you are now using a plasticizer, we know a barrel of C-202 would prove its superiority.

In the hardened state of concrete cement dispersion decreases permeability and absorption and produces strength equivalent to those obtained with a high early strength cement. These increased strengths permit earlier removal of forms and more rapid re-use of the same forms. The greater plasticity and homogeneity of the mix is said to assure greater freedom from corrosive defects such as honeycombing and sand streaking.

PROPORTIONING

IMPORTANT: The concrete-units manufacturer has control to a large extent over the properties of his concrete through careful selection and combination of fine and coarse aggregate and in the proportioning of the total aggregate to the cement. The combination of fine and coarse aggregates which will develop the maximum strength may produce units that have too rough a texture and edges that are too uneven to make the product salable. The grading that might result in the maximum fire resistance might not be best for maximum strength or minimum absorption, particularly with building units. For this reason the combination of aggregates and the proportion of aggregates to cement are usually a compromise which will produce to the highest degree all the desirable characteristics in the finished product.

MIXTURES: Once the general make-up of the mix is selected, it is evident that there must be some means of duplicating it in practice, if uniformity and quality are to be maintained and economy effected. This can be done only by actual measurement of the ingredients and by keeping a record of the proportions and kinds of materials used. This, of course, precludes the use of pit-run or crusher-run material.

Some systematic method of expressing the quantities used must be employed if comparisons are to be made. In practice work it is usual to express the proportions as volumes of dry materials, with cement as a basis, the order of the ingredients being cement, sand and a coarse aggregate. The amount of mixing water is usually expressed in gallons per 94 lb. sack of cement. In regular production the operator will do well to proportion the dry materials by weight. One of the biggest advantages of weight proportioning is the ease of making proper allowance for the moisture content of the fine aggregate. However, whether measurement by weight or volume is adopted, it is important that extreme accuracy always be used.

When aggregates are stored in overhead bins, good use can be made of measuring chutes or weighing devices to measure out the desired proportions. The employment of modern spiral blade mixers necessitates the use of feeding devices which automatically maintain the desired proportions of materials. The means of measurement will depend largely upon the amount of output and the size of mixer and plant equipment but, whether elaborate or simple, some means of control should be provided and occasionally a check should be made on their operation.

STRENGTH: Whatever the proportions used, the finished units must meet the A.S.T.M. specifications or local building code requirements. The only really reliable way for establishing definitely the proper proportions of aggregate to cement to obtain the required strength is through tests made in a properly equipped laboratory. These tests should be run frequently when changing materials or mixes and after that only often enough for checking.

In general, the coarser the grading of the aggregate, the greater the strength of the unit for any given cement content, provided there are sufficient fines in the aggregate to make the mixture workable with the chosen molding equipment. However, the grading must not be too coarse or there will be breakage in handling the units from the machine and the surfaces and edges may be too rough and irregular.

With all the fine aggregate passing a #4 sieve and the coarse aggregate graded from 1/4 to 3/8 inches, the maximum proportion of coarse material can be used to advantage in building-units work is about 50% of the total aggregate used in the mixture. Generally not more than 40% of coarse material gives the desired combination and in a very few instances only 25% of coarse aggregate will produce a unit which has the greatest strength for a given amount of cement. The proportions of cement to be used for any given combinations of fine and coarse aggregates can only be determined by trial. Trial mixtures containing 25, 35, 45, and 55% of coarse aggregate graded from #4 mesh to 3/8 inch mixed with the fine aggregate should be made with different proportions of cement to the total aggregates 1:6, 1:7, 1:8, 1:9, 1:10, and 1:11, by damp loose volume of mixed aggregate.

Where waste material containing little or none of the coarser particles is to be used, more cement will be required since there will be more surface area to be cemented together. These coarser particles will probably vary from proportions of l:3 to 1:6, but the need of tests to determine the required strength is always the deciding factor. In general, the coarser the sand the stronger will be the resulting concrete or concrete block.

At the machine itself the first indication of the suitability of aggregate combination and cement-aggregate proportions will be apparent. If the appearance of the surface and edges is satisfactory, if the units being produced can be handled easily and quickly without broken webs and corners, the mixture is probably suitable with regard to appearance and handling.

After setting aside the first two and the last two units from each trial mixture, three units from each mixture should be selected and cured according to ordinary plant practice and kept for testing at 28 days by a recognized testing laboratory. From this original group of tests the manufacturer can tell within a relatively narrow margin the proportions of aggregate to cement that are necessary to produce the strength required by the A.S.T.M. specifications or local building codes.

The importance of uniformity of grading of the aggregates should always be borne in mind. If obtained from well-established commercial plants, little difficulty will be encountered. However, if irregularity of gradation occurs, it may be necessary to change the source of supply or install screens to make the separation.

DEFICIENCY OF FINES: If the units in the trial batches break easily when being handled from the machine to the rack and from the rack or other transporting device to the curing room, the probability is that the fine aggregate is deficient in fines. A screen analysis is then in order and if such a deficiency is shown to exist, the addition of small amounts of fine sand, stone screenings or other finely-divided aggregate will aid in making the concrete workable and easily handled. With washed fine aggregate it frequently happens that too much of the very fine sand is washed away and this accounts for the deficiency mentioned. In cases such as this it is frequently possible to overcome the deficiency by the addition of a greater amount of air entraining agent to the batch. Close attention should be paid to the condition and a determination between very fine sand and silt should be made. The presence of very fine material should always be limited to the bare requirements to make a unit that can be handled without cracking or breakage; an excess of fine cuts down the strength and results generally in higher production costs. Manufacturers who use the Inspection and Certificate Service of the Underwriters' Laboratories have a positive guarantee that their product will meet A.S.T.M. specifications. This service usually eliminates the necessity of further commercial tests.

EXCEEDING REQUIREMENTS: The manufacturer should always aim for at least 100 lbs. per square inch of gross area more strength than the minimum required. Many of the successful producers have attributed their success to the fact that they made a product so far superior to that demanded by building-code requirements that all resistance to concrete masonry has been overcome. Architects and builders will be quick to recognize a quality product and specify the product of that plant which manufactures it. One plant in a large metropolis, where the building code demanded only 750 lbs. per square inch compressive strength, found business lagging, revamped its operating procedures so that all the concrete blocks now being made average 1200 lbs. per square inch, and it is now operating at capacity because architects and the building trade immediately accepted the superior product.

QUANTITY OF MIXING WATER: Machine-made concrete units are produced by pressure and vibration and thus require much less water than ordinary concrete which is poured into forms. Since too much water weakens ordinary concrete, producers of that material are always cautioned against the use of sloppy mixtures; however, quite the reverse is true with machine-made units. The tendency is to use too little water on vibrating machines. Water should be added up to the point where the freshly-stripped unit will just stand up and where the surfaces will show occasional web-like water marks, although their presence on the face of building units may be objectionable. Experienced operators are usually able to test the mixture by squeezing a handful of it. When traces of moisture show on the outside of the squeezed mass, it is usually considered to be about right. Columbia can always be relied upon, however, for good advice on this subject. With porous aggregates, mixtures somewhat drier than those used for dense aggregates are generally recommended for the vibration pressure method, as this will produce a fairly coarse texture which is desirable with building units for the application of plaster or stucco.

Of course, in making units such as precast slabs, burial vaults, large pipes in which concrete is poured into forms and similar units, the water content will be somewhat higher than when machine-made units are being manufactured, since it must flow readily into each small section of the mold. However, many of these molding jobs are being augmented today by the use of vibrating equipment which aids in compacting the concrete and jogging it into all the recesses of the forms, allowing the use of less water than with the straight-pour process. Here again, however, the concrete producer must rely upon the manufacturer of the particular equipment he is installing and any advice given here would be too general for use in specific cases.

DENSITY: With dense aggregates, the proportions which will produce the product with greatest density are generally those which contain the maximum amount of coarse aggregate and still contain enough fine aggregate to produce a smooth surface. With porous aggregates used in the production of lightweight units, the amount of the material in the mixture passing a 50-mesh sieve is generally limited; and in addition, more of the coarse particles are used to produce a unit of less density and lower weight. This quality is generally desirable .except where fire resistance or watertightness is important.

MIXING

TIME OF MIXING: The relatively dry mixture used in the machine manufacture of concrete masonry units requires longer mixing than is necessary with ordinary concrete for monolithic work. Since the units are stripped immediately after being molded, the concrete must be well under the slump point. Despite this, the water-cement-ratio law still applies, and adequate strength can be obtained only if the mixing time is sufficiently long to coat each particle of aggregate with cement. One of the most prevalent errors in plant design is the failure to provide sufficient mixing capacity, with the result that equipment is badly overloaded or the time of mixing is seriously curtailed.

There exists a considerable difference of opinion as to just what mixing time is necessary to accomplish thorough coating of the particles. Some producers mix their materials for as long as 15 or 20 minutes, and feel that the additional investment in mixing capacity is well repaid by the excellent strengths attained by their units.

More conservative authorities, however, seem to agree that the increase in strength for mixing beyond six (6) minutes is not sufficient to be economically justifiable. The time should be measured after a1l the materials are in the mixer. Good practice dictates that with dense-aggregate concrete, the cement and aggregate should be mixed for about a minute before the water is introduced, or until the mass is uniform in color.

With porous or lightweight aggregates, one-half to two-thirds of the total mixing water required should be mixed with the aggregates for two (2) or three (3) minutes before the addition of the cement. This practice is necessitated by the relatively high absorption of the materials. The pre-mixing fills the pores of the cellular particles with water before the cement is added, preventing dry cement from getting into the pores where it would be ineffective. After the remainder of the water has been added at least six (6) minutes mixing time should be allowed.

Poured precast-concrete products require comparatively wet concrete, and the gain in strength resulting from increased mixing time will not be as apparent as in the case of dry mixes. However, a mixing period of three (3) minutes is not too long for poured concrete; and where water tightness is important, as in the manufacture of burial vaults, good practice is to mix up to five (5) minutes.

TYPE OF MIXERS: Although batch mixers of all sizes are used in the concrete products industries, the larger are in far more general use. A given charge of materials is placed in the batch mixers, mixed, and discharged before the next lot of materials is added. Since the sole function of the mixing operation is to secure thorough, uniform mingling of the materials, it is probable that any of the machines will give satisfactory results.

Batch mixers are manufactured in a wide range of sizes, and with various combinations of mechanical features. Since, even in a given size they vary considerably in initial cost, the buyer may well find himself confused when he is compelled to choose. The desirability of extremely rugged construction, such as Columbia has long been famous for, is a good point to keep in mind when selecting a mixer; a light machine, even though it may be adequate for the mixing job, may prove to be highly vulnerable when some foreign object is inadvertently introduced. Replace ability of parts subject to wear is another vitally important factor to be considered.

CAPACITY AND RATING: Manufacturers' recommendations with respect to capacity and speed rating of mixers should be followed to the letter. Overcharging of the mixer or increasing its speed will be very likely to cause serious damage and will in no case yield benefits commensurate with the risk involved.

CARE OF MIXERS: The interior of any mixer, regardless of the type or make, should be thoroughly cleaned at the end of each period of operation or more often if found necessary. This will prevent a gradual accumulation of concrete on paddles and the liner plates and will assure the maintenance of maximum capacity and efficiency. Parts subject to wear should be inspected frequently and replaced well in advance of impending failure to prevent serious damage and interference with production.

PROCESSES: Concrete building units are molded by vibrating, by the application of pressure, or by a combination of these methods. In recent years, vibration has come to occupy and increasingly important position in the industry and many of the high – capacity machines no on the market apply vibration in some manner to the mold box. Vibrated concrete units easily meet density and strength requirements and have good surface texture. *(Also See Columbia CVT Columbia Vibration Technology)*

THE CURING OF CONCRETE MASONRY UNITS

The curing of concrete masonry units is an essential part of the daily production schedule of every block producer. Simply stated, it is a necessary process which provides adequate moisture and heat to act on the chemicals in the concrete and to provide sufficient moisture for the complete hydration of the concrete. In order to accomplish the purposes of curing, the block producer has open to him a few methods for furnishing heat and moisture to the concrete masonry unit so that he will have a product which has proper compressive strength, moisture contents and uniformity of color in the most effective and economical manner.

In southern or tropical climates, outdoor temperatures remain high and it is only necessary to keep the product wet for a forty-eight hour period. This is accomplished by sprinkling the units periodically. However, it should be mentioned that even in tropical climates the emphasis has been on steam curing because of the uniformity of control of heat and moisture. Also, with steam curing, the steam is generated automatically, it can be closely controlled, and there is no need of having failures due to human element. We will therefore concern ourselves with the two generally accepted and universally accepted methods of curing. They are:

I. STEAM CURING OF CONCRETE MASONRY UNITS AT ATMOSPHERIC PRESSURE

This method utilizes steam curing kilns built out of concrete block generally with slab-type roofs. Low pressure steam is admitted to these kilns from a low-pressure steam boiler. The steam is admitted live to the kiln through a pipe with an open end exhausting into the kiln preferably at the bottom of the kiln.

The steam is at about 10 to 12 pounds pressure (under 15 pounds) and this provides circulation of the steam and also moisture and temperature for steam curing the blocks.

In some cases, the moisture and heat is provided for the kiln by locating a gas burner at one end of the kiln firing against an open tank of water which provides a steam vapor for furnishing moisture. At the same time, the combustion gases from the gas burner provide heat.

II. STEAM CURING OF CONCRETE MASONRY UNITS AT HIGH PRESSURE

This method is one utilized by a lesser number of plants than atmospheric curing. It requires a large high pressure steam boiler, high pressure steel cylindrical autoclaves, special quick opening doors able to withstand and operate with steam pressures of 150 pounds and more. This high pressure steam produces temperatures in excess of 350 degrees and will produce concrete masonry units which will reach ultimate strengths and lower moisture contents in twenty-four hours. However, this system is most costly, requires much maintenance, supervisory engineers, and can cause replacement at an early date of steel racks due to the deteriorating influence of the high pressure and temperatures. Although there is a saving in cement in that silica sand can partially replace the cement, the other costs make this system more costly and a premium has to be charged for autoclaved blocks.

ATMOSPHERIC STEAM CURING

CURING ROOMS OR KILNS: In atmospheric curing, it is essential to curing rooms or kilns which will be used to hold the block on racks in order that they are subjected to steaming as required to bring up the blocks to the proper strengths for cubing and later delivery on the job.

Generally speaking, curing rooms should be large enough to hold a two-hour production of block each. In this way, with present high-speed, three-block machine, the kiln would hold from 2000 to 2800 blocks. Exact dimensions of the kilns will vary depending on the size of the racks and the space available in the plant. The curing rooms should be tightly constructed as any excessive heat loss will cause higher fuel costs and will build up excessive condensation along cold spots or where there are steam leaks. The outside walls generally are constructed of 12” block with inner walls or partition walls made of 8” block. The roof is made of poured concrete or concrete slabs as this type of roof will last much longer in presence of heat and moisture at the roof levels.

Kiln heights should be kept down to about 6” above the height of the highest unit and a slight slope put in the center of the roof so the moisture can run off to the side walls of the kiln and not drop on the product.

The maximum amount of insulation should be used with such possibilities as filling the core of the blocks with insulating material such as zonolite and covering the roof with gravel. Use of roof slabs will allow for expansion joints.

For doors, there are canvas and rubber impregnated plastic curtains which will adhere to a frame on the kiln and hold the steam most effectively. These are quite inexpensive and are not subject to the damage will occur with hinged or sliding doors which also may be used. With automation in most plants, the tendency is to have the kiln openings in one end of the kiln from which the racks are placed in the kiln and also taken out. With one opening, there is less opportunity for heat loss.

It is absolutely essential in constructing kilns that provisions are made for proper drainage of condensate. A gradient of about one inch in twenty-five feet will generally take care of the water that will accumulate from the condensation of the steam. Sealing coating may be used for sealing the walls of the kilns to again prevent excessive heat loss and will preserve the walls of the kilns.

We have generalized on the subject of kilns, but Columbia Engineering
Department will be able to design proper kilns based on the production of the plant and area available for the kilns.

For further information of a more detailed nature, we refer you to:

(1) Shore, W.J., “How to Build Well-Insulated Block Curing Kilns”, Concrete Products,

(2) Copeland, R. E., “Kilns and Appurtenant Facilities for Low Pressure Steam Curing”,

(3) Dikkers, Robert, “Steam Boiler Size Requirements for Curing Systems”, National Concrete Masonry Association.

PROCEDURE FOR LOW-PRESSURE STEAM CURING: The procedure for low-pressure steam curing as determined by the Committee on Low-Pressure Curing of the American Concrete Institute, Study groups of the NCMA and others consist generally of the following method:

When the kiln is completely filled, the door is closed and the blocks will be allowed to set before the steam is turned on. This is what is known as the pre-set method. No steam is turned on for between one to three hours. The actual timing for the pre-set period will be determined by the block plant operator after determining the length of period which is most advantageous for the final product. The reason for this pre-set is to prevent thermal shock which can cause crazing cracks in the block due to flash setting of surface concrete.

Following the pre-set period, steam is introduced into the kiln. Generally, steam is introduced at the center of the kiln through a pipe nozzle at a point just below the bottom tier of the racks. We utilize this low location of feed because of the fact that steam will naturally flow to the top of the kiln and it is advantageous to have it flow through the product and not simply be introduced at the top of the kiln where it will normally remain at the top and have to infiltrate to the bottom. Another problem can be excessive moisture at the roof if the steam is introduced at the roof level.

Steam pressure should be around ten to twelve pounds providing 238 degrees of live steam with the aforementioned pressure circulating the steam throughout the kiln.

Before the blocks are placed into the kilns, we should be sure that the kiln temperature is a minimum of 90 degrees F. A lower temperature will retard the setting of the cement in the blocks and affect the later strength of the product. What we attempt to do in the kilns is to bring the kiln temperature up to equilibrium of dewpoint. This would be 100% relative humidity and the block will not take any more moisture and in fact will give off moisture. To continue steaming after this equilibrium temperature had been reach is a waste of fuel and can, in some cases, be damaging to the blocks.

On lightweight block, the dewpoint temperature is about 170 degrees F. while the dewpoint on heavyweight block is around 160 degrees F. An exact temperature for your particular kiln can be determined by using a sling hygrometer which will give a wet and dry bulb temperatures so the equilibrium temperature can be determined. Cement Company Engineers generally have these instruments and will allow plants to use them to make the equilibrium of dewpoint temperature determination.

Once the equilibrium temperature is reached, the steam is turned off. In raising the temperature to the equilibrium temperature, the steam should not be elevated more than one degree a minute. Therefore, were you to attempt to reach 160 degrees F. in heavyweight block from a 90 degree start, your b oiler would be sized to provide a 70 degree rise in roughly one hour and ten minutes. Many boilers are sized to bring up temperature at the rate of 40 degrees and hour which will allow you to steam the kiln in two hours.

Following the steaming period and after the dewpoint or equilibrium temperature has been reached, the steam is turned off and the blocks allowed to soak in the steam overnight or until it becomes necessary to use the kiln.

Many block plants utilize kiln controls consisting of steam-indicating controllers and timers which will time out the pre-set period then begin the steaming cycles and automatically shut off the steam when the equilibrium temperature has been reached. Exhaust fans are also used on the kilns before unloading to prevent excessive condensate and fog coming into the producing area and for removing surface moisture from the blocks.

For further information of a more detailed nature, we refer you to:

(1) Committee 517 – Report- "Standard Recommended Practice for Atmospheric Pressure Curing of Concrete", available from American Concrete Institute, Detroit, Michigan.

HIGH PRESSURE STEAM CURING

EQUIPMENT: In this type of curing, as outlined above, it is necessary to use high pressure, cylindrical vessels which are capable of withstanding pressures in excess of 200 pounds. These cylinders are much more costly than average atmospheric kilns. The piping for this high pressure of autoclave setup is most extensive, requiring special blow-downs and other appurtenances required in dealing with high horsepower boilers and high pressure steam. Each autoclave holds from 2500 to 6000 block with specially constructed racks. The racks in many cases are constructed pyramidally so that more blocks can be loaded in the autoclave due to the fact that we are loading a cylinder.

PROCEDURE: The freshly made units are wheeled into the cylinders, the closures are made, and steam at 120 lbs. per square inch gate pressure or more is turned on, the temperatures inside reaching 350 to 360 degrees F. in about 3 hours. After 7 to 8 hours of curing, the steam is turned off and the pressure is rapidly lowered during a ½ hour period to atmospheric pressure after which the units are removed. In general, units cured in the manner will have strength at least equivalent to that obtained by 28 days of continuous moist curing at 70 – 80 degrees F.

Besides accomplishing whet takes place in the ordinary curing cycle, the high temperatures and high pressures within the cylinders produce different hydration products and thus eliminate the principal cause of volume change in the units, at the same time allowing the use of a smaller quantity of cement to produce a given quantity of product. Experience has indicated that if units cured by this method are laid in a wall in the same dry state they attain after cooling to normal temperatures after removal from the kilns, there will be a marked reduction in volume change under constant temperature humidity conditions, thus minimizing the amount of cracking caused by drying shrinkage.

For more detailed information, we refer you to:

(1) Report of High Pressure Curing Committee, #516, "High-pressure Steam Curing Modern Practice and Properties of Autoclaved Products", American Concrete Institute, Detroit, Michigan.

DRYING AND CARBONATION

Recently many concrete b lock plants have utilized artificial drying and carbonation of block in addition to the regular steam curing. This has been done to achieve a lower moisture content on the block immediately after steam curing in order to meet ASTM specifications of 40% moisture content on the block at delivery. Army Corps Engineers have gone further and certain government jobs, they have asked for a moisture content of as low as 30%.

The drying of concrete masonry units has been achieved by the use of gas burners used in dryers in conjunction with high velocity fans to send high temperature air through the kilns or special drying rooms to pick up moisture from the block. The theory being that the higher temperature air, being in an expanded state, will absorb moisture from the block. As the moisture is removed from the surface, more will come from the interior of the block to the surface and this will be absorbed by the hot combustion gases. The vapor-laden air is then vented to the outside.

Carbonation is a process where the combustion gases from the gas burner are directed to the product in the kilns or special drying room. Such combustion gases contain about 10% to 15% carbon dioxide. This chemical (CO_2) reacts with the chemicals in the concrete and has the effect of carbonating the block. It is believed that such carbonation, whether completed or partial, will add to the compressive strength of the block.

With this drying and carbonation, lower moisture contents are achieved. Blocks can be delivered earlier to the job. It follows also that with lower moisture content, higher compressive strengths can be achieved.

For more information of a more detailed nature, we refer you to:

(1) Kuening, W.H. and Carlson, C.C., "Effects of Variations in Curing and Drying on the Physical Properties of Concrete Masonry Units", Development Department Bulletin D13, Portland Cement Association, 1956 -

(2) Toennies, H. T., "Artificail Carbonation of Concrete Masonry Units", ACI Journal,

CURING – GENERAL SUMMARY

We have attempted in a general way to outline the methods of curing available to the block plant operator. However, if a block plant operator contemplates changing his present curing or building a new plant, a very careful study should be made of his production requirements and movement of the concrete products through the plant.

The objectives of the block plant operator in terms of daily production can be translated into a curing system to meet his needs for a product that fits into his operation and meets the requirements of his market. This entails detailed study and recommendations on proper sized kilns, boiler size, degrees of instrumentation needed, exhaust fan system and whether a drying and carbonating system is indicated. All of this is part of the "Turnkey type" of engineered planning of new block making facilities which Columbia Engineering is able to offer.

TEXTURE

PRODUCING TEXTURES: The two principal ways of varying the texture of the unit are: (1) varying the grading of the aggregate used or the consistency of the mixture and (2) the use of manual or mechanical means to give variety to the texture obtained by (1). The second is usually accomplished by the use of a fine water spray or by the use of wire or bristle brushes to texture the face of the unit immediately after molding. When texturing is accomplished by manual means, the work is frequently rotated among the crew to secure suitable variations. Operating the texturing tool first with on hand and then the other also helps to obtain variation.

When the texturing is done by spraying, care should be taken not to etch the surface too deeply nor to wash the cement out of the face. It is recommended that a richer mixture be used when the texturing is done by this method and that the spraying be continued only long enough to remove the surface film and expose the aggregate. Units with exposed face shells less than 1-1/4" thick after texturing should not be used in walls exposed to the weather.

Surface effects are also obtained by sprinkling coloring materials or ground mica on the face of the mold on down – face machines before molding. Monumental cast-concrete pieces are sometimes finished by grinding with Carborundum stone or employing regular stone working machinery which grinds and polishes the surfaces.

The cost of the various colored textures on building units will probably range from 2 to 12 cents per square foot in addition to the cost of the units themselves.

SURFACE CRAZING: Small check marks or cracks, usually of a web-like nature, sometimes seen on concrete units are known as "crazing". When the surfaces are moist, "crazing" is particularly noticeable. It is a result of volume changes incident to variations in moisture and temperature and the setting of the concrete. With very thin, rich coatings on relatively lean bodies, "crazing" generally appears. "Crazing" is a problem that has not yet been solved. However, much can be done to lessen the tendency to "craze" by using leaner facing mixture, providing thorough curing, and avoiding excessive troweling of the surfaces, not using too much water, and avoiding the appearance of surface film. Exposure of fresh concrete to the sun and the wind should also be avoided.

The product gives the architect a new exterior finish in a wide range of colors, a variety of sizes and even a choice of split finishes. For color, mineral pigments are usually incorporated in the batch when mixed. This process preserves the integral character of the concrete, which was entirely lost in the once-popular "rock-faced" unit, now practically extinct in the industry.

Concrete bricks are being turned out in solid colors in modern plants and with textures that yield nothing to burned-clay or shale-face bricks in the way of appearance of durability. Bricks are also colored of glazed by spraying on a surface application, while blocks are almost universally colored by facing methods to reduce the cost. The successful use of dry pigments requires thorough dry mixing of the cement and pigment to obtain uniformity of distribution and color.

Sometimes a small mixer is used to blend the cement and color dry before adding them to the concrete mixture to be colored. It is important that a permanent record be kept of the treatment as well as the materials used in making colored mixes, since such data is necessary if results are to be duplicated.

There are a number of practical methods for producing attractively colored as well as textured surfaces for concrete-masonry units.

COLORING BY MINERAL OXIDES: Color may be obtained by the use of pure mineral oxides which are especially prepared for use in concrete and are mixed with the cement and sand facing. These are available from white (obtained by using white cement) through yellows, buffs, reds, greens, and blues. Ordinary mortar colors are not satisfactory. Depth of color or varying shades from light to dark can be obtained by controlling the amount of mineral oxide used in the facing mixture or by mixing two or more primary colors together.

COLORED AGGREGATES: In addition to the above method of obtaining color, colored aggregates, with or without the use of mineral oxides, produce pleasing color effects used in the facing mixture. When colored-aggregate facings are made, they are usually given a dilute muriatic-acid wash to remove the cement film on the surface of the exposed aggregate.

This also etches a slightly-roughened texture on the surface.

OTHER COLORING METHODS: Another method consists of coloring the concrete building unit immediately after molding it by spraying on the exposed face a Portland-cement paint of the desired color. Two-tone effects can be obtained by this method, using the first coat as a base color or a suitable contrasting color after the wall has been erected.

Colorcreting is a process of pneumatically applying a cementatous material to exterior and interior masonry surfaces. It is used for beautifying and weather-proofing stucco buildings, also walls built of brick, block, etc. The Colorcrete material becomes an integral part of the masonry to which it is applied. It is supplied in a wide range of colors and shades.

Colorundum, a product of A.C. Horn Company, forms a colored plate integrally with the cement finish, similar to that of ceramic tile. It is a dry powder composed of coloring mediums, fused aggregates, water repellent compounds and hardening elements, plus cementatous binders.