opening automatically to the full diameter of the tube while being withdrawn. The point of the form closely resembles the jaws of an alligator. At the same time the form is being withdrawn, the concrete is deposited.

It is so evident that concrete is vastly superior to wood in the construction of piles that it is almost superfluous to mention the points of superiority. Concrete is not subject to rot or the ravages of the teredo worm, neither can the piles constructed of concrete be destroyed by fire, and no cost is attached for repairs. While it is not possible to give accurate statistics as to the life of a wooden pile, as it varies so much under different conditions, yet we know that in some cases a wooden pile is rendered worthless in a very few years, especially when the surrounding material is composed of rotted vegetation, or where the pile is exposed by the rise and fall of tides. It is also impossible to state the exact cost of a concrete pile, as it varies also according to conditions. Ordinarily speaking, a concrete pile will cost from one and one-half times to two times as much as a wooden pile; but in order to illustrate where a saving can be made, the following extract is given from a report on the piles driven at the United States Naval Academy at Annapolis, Md.:

"The original plans called for 3,200 wooden piles cut off below low water with a capping of concrete. To get down to the low water level required sheet piling, shoring and pumping, and the excavating of nearly 5,000 cubic yards of earth. By substituting concrete piles, the work was reduced to driving 850 concrete piles, excavating 1,000 cubic yards of earth and placing of 1,000 cubic yards of concrete."

In the work mentioned, the first estimate for wooden piles placed the cost at $9.50 each, while the estimate for concrete piles was placed afterward at $20 each, yet the estimate based on the use of wood piles aggregated $52,840, while the estimate based on the use of concrete piles was $25,403, or a total saving in favor of concrete of over $27,000.

In several instances piles have been uncovered to their full depth, and they were found to be perfectly sound in every particular. By surrounding the operation with the safeguards provided, it is almost impossible to make a faulty pile. The concrete is made as wet as good practice will allow. Constant ramming and dropping the concrete from a considerable height tend to the assurance of a solid mass, then the target on the ramming line or the introduction of an electric light into the form shows what is being done at the bottom of the form.

Floors, Slabs and Roofs.—The system of construction for floors, slabs, and roofs is determined by the extent of the work and the nature of the loads to be carried. If intended for small buildings and offices, the items can be made before erection (Figs. 9 and 10); but in the case of warehouses, factories, piers, and jetties, where live loads and vibratory stresses have to be borne, a monolithic structure is secured by building in molds directly on the site. For the lighter classes of monolithic structure, expanded metal is admirably suitable; it is also much used for the roofs of reservoirs, and for thin partition walls. The meshing is simply laid over the ribs or floor beams, which have been already erected, and the green concrete is applied to the required thickness, being supported from below by suitable supporting work, which is removed as soon as the concrete has set. In cold storage factories, the floor beams and ceilings are invariably erected first, the floor being laid afterward. The ceiling is then solid with the floor beams on their under side, and the floor is solid with them on their upper side, the air space between being a great aid to the maintenance of a low temperature for refrigeration.

In the Monier floors the reinforcement consists of round rods varying from ¼ inch to ⅝ inch diameter. The rods are spaced at about six times their diameter, and are crossed at right angles, being connected by iron wire bound round them. This artificial method of securing the rods takes considerable time, and is thus a somewhat costly process. To produce continuity of metal, the different lengths of rods are overlapped for about 8 to 16 inches, and bound with wire.

The Schlüter are similar to the Monier floors, but the rods are crossed diagonally, and the longitudinal rods are of the same size as the transverse ones. The Cottancin floors have their rods interlaced like the canes of a chair seat or a basket, and the Hyatt floors have square rods with holes through which small transverse rods pass. Over fifty systems of reinforcing are in use, and in most cases the only points of difference are the shape of the section and the method of attachment and adjustment.

Beams.—It is obvious that, as the span increases, a limit will soon be reached beyond which it is not economical to use plain floor slabs, for their dead weight becomes of such magnitude as to prohibit their use. We have thus to resort to a division of the main span by cross beams resting on columns, and the floor is laid on these beams, which are arranged to take as much of the load as to render it possible to reduce the thickness of the floor within reasonable limits. Reinforced concrete beams are typical of the type of construction in which the merits of two component materials are made to serve a common end; but in the particular case of steel and concrete, the actual part played by the steel is not at all well understood.

Speaking generally, beams do not differ in constructional details from floors. The same reinforcement is used in both, the only difference being, that as beams are usually deeper than floors, the shearing stresses become more pronounced, and greater provision has to be made for them by a liberal use of stirrups or vertical binding rods. In some systems the reinforcement consists entirely of straight rods, disposed in any part of the beam where tensile stresses are likely to be called into play. In others, specially bent rods are joined or welded to straight rods, and when welding has to be done it would appear that wrought iron is more suitable than steel.

It is usual to arrange the dimensions of the beams so that the whole of the compressive stresses are taken by that portion of the concrete on one side of the neutral axis; but in some cases, as with continuous beams or heavy beams of small depth, a proportion of the reinforcement is distributed along the compressed portion of the beam, the steel rods either taking up the excess of compressive stress over that at which the concrete can be safely worked, or else taking up the tensile stresses at the places where they occur over the supports. As a general rule we may take it that the economical depth for a reinforced concrete beam, freely supported at both ends, is one-twentieth the span, and is thus approximately the same as that of a steel girder of equal strength. Reinforced concrete beams are now made for spans up to 100 feet for buildings, and 150 feet for bridges. But for each class of work beyond this limit, the weight becomes excessive. Several arched ribs for much greater spans have, however, been successfully built.

The beams are made in much the same way as piles and columns; they can be made in sheds on the site, or in the actual position they are to occupy when finished. The ceiling and beams are erected first, the floor being afterward worked on the top of the beams. We thus obtain a very perfect monolithic structure in which any vibration set up by machinery, falling loads, etc., will be of much less extent than with an ordinary type of building, in which there is often a great want of rigidity, the beams and arches being loosely connected and able to vibrate independently of other parts of the structure.

Concrete being as weak in shear as in tension, provision is also required to take the shearing stresses. Some American designers have to this end patented special forms of reinforcement bar, in which each main tension bar has projecting upward from it ties inclined at an angle of 45 deg. (Kahn system). These extend to the top of the bar and take the tensile stresses arising from the shear. The corresponding compressive stress at right angles to this is carried by the concrete. The system is efficient, and on large spans, where weight must be reduced to a minimum, it has its advantages.

Thus in the Ransome system (Fig. 12) the shearing stresses at the ends of a beam are taken up by inclined reinforcing rods imbedded in the concrete at the junction of beam with column.

Arches.—Concrete has long had an extensive application in the building of arches, but until the introduction of reinforced concrete the arches that could be economically and safely constructed were limited to spans of a few feet. The general rule that the line of resistance fell within the middle third had to be observed for simple concrete arches, as for those in brickwork and masonry; and the thickness of the arches at the crown was thus approximately the same whether built in either of these materials. The introduction of steel reinforcement, however, made it possible not only to reduce the thickness of the ring for a given load-carrying capacity, but by suitably providing for the tensile stresses to enable arches of much greater span and smaller rise to be built. Some general types of arches in reinforced concrete are shown in Figs. 13, 14, 15, and 16. Fig. 13 shows an ordinary arch with top and bottom armature. In many cases where the tensile stresses can safely be carried by the concrete the top armature is omitted. In the Melan arches, shown in Fig. 14, the top and bottom armatures are connected by ligatures, and in the Hennebique arches (Fig. 15) stirrups are used. As a general rule, hinges should be built at the springings and the crown, for the calculations are much simplified, and the line of resistance goes through the hinges; the arches also adjust themselves better to the load and to any slow temperature changes, and when the centering is struck the arch can better take its bearings without cracking. The methods of calculation for arches are as numerous as those for beams, and generally speaking are as irrational. The Monier system is the one most generally adopted, and over 400 bridges built on this system now exist in Europe. In America expanded metal and Clinton electrically-welded fabric are often used. An example of the latter construction will be found in Fig. 17.

CONCRETING THE JEROME PARK RESERVOIR.

The concreting of the westerly basin of the Jerome Park Reservoir, lying near the northerly limits of New York city, is, we believe, considerably the largest single job of concrete paving as yet undertaken. The total area of floor and side slopes of the basin is 101.25 acres, and the whole of this surface was coated with a layer of concrete, which varied in thickness from 6 inches on the floor to a maximum of 30 inches at the top of the slopes.

The figures of quantities involved are very striking. The work called for the use of 625 carloads, or 94,000 barrels, of Portland cement, 1,250 carloads of sand, and 3,125 carloads of crushed rock—a total of 5,000 carloads in all, which had to be hauled into the basin, distributed, mixed, and carefully laid in place. The task is further magnified by the fact that the preparatory leveling down and grading of the floor and slopes involved the taking out of the basin of another 5,000 carloads of excavated material.

The Jerome Park Reservoir was designed to act as a local storage and distributing reservoir within the city limits. It is divided by a central wall running approximately north and south, which divides it into a west basin (completed last year, and now in use with a maximum full capacity of 773,400,000 gallons) and an east basin, which is about 8/10 excavated and when completed will have a capacity of 1,130,000,000 gallons, or a total capacity of 1,903,400,000 gallons. The reservoir is supplied by the old and the new aqueducts, both of which lead from the great Croton Reservoir. At the northerly end of the basin is a large gatehouse, No. 7, through which the water can be discharged into either basin of the reservoir; or, if preferred, it may be taken through the conduits, which are built with the divisional wall, to the central gatehouse, No. 5, where the water can be let into either basin, or sent through the 48-inch pipe lines laid on the floor of the reservoirs (of a pair of which we present an engraving), across the reservoirs to gatehouses Nos. 2 and 3, on the westerly margin of the reservoir, or to gatehouse No. 4, on the easterly margin. From these gatehouses the water may be fed to the city mains, or returned into the basins for the better circulation of the reservoir. From gatehouse No. 4 a 48-inch pipe connects to supply the Jerome Avenue high-service station, or, if desired, the water can be passed on from central gatehouse, No. 5, south through one of two 11-foot circular conduits built in the division wall, to be discharged at the southerly end of either of the reservoirs for the purpose of thorough circulation.

The water received through the old aqueduct can be let into either basin at the northerly gatehouse, No. 7, or it may pass south through the division wall around gatehouse No. 5; or it can be diverted into this gatehouse and into the pipe lines or the reservoir basins.

It is evident that in carrying through a job of concreting on this great scale, the question of its cost was very largely dependent upon the judgment shown in disposing of the large force of labor and the enormous amount of raw material to the best working advantage. A gap was left in the central dividing wall of the reservoir, through which was laid a broad-gage track for hauling in the material. Speaking generally, the plan of operation was to lay approximately parallel tracks, north and south, as they were needed, spacing them 200 feet apart. Each track became a center from which the concreting was carried out on either side for a distance of 75 feet. Scattered along the tracks at distances which were found to be the most advantageous, were fourteen concrete mixers, and the supplies of cement, sand, and broken stone were hauled into such a position, that in juxtaposition to each mixer was a carload of stone, another of sand, while the cement, in bags, was piled up conveniently to a runway leading to the hopper of the mixer.

The concreting was laid in alternate strips about 12½ feet wide, extending 75 feet at right angles to the tracks, 75 feet being found to be the maximum distance at which the work could be economically done. The strips were laid with approximately 12½ foot spaces between them, and after the first strips laid had become hard or set, the intervening spaces were also concreted. As soon as the whole area controlled by one track had been completed, the tracks after ten days were shifted onto the concrete. and commencing at the inner end thereof, the concreting of the space on which the tracks had lain was laid down, thus giving a fair, unbroken floor. Generally speaking, the batteries of mixers were arranged in twos, threes, and fives, according to the preparation of the ground. The concrete consisted of one of cement, two of sand, and five of broken stone, and for the mixing of it there were altogether fourteen mixers employed on the bottom of the basin, and two on the northerly slope.

At the time of the commencement of work, April 1, 1905, about thirty acres of the southerly end of the basin had been concreted. The remaining 71.25 acres were completed between April 1 and October 1, 1905, by a maximum force of 1,200 men; and this in spite of the fact that one month's time was lost through a strike.

During the progress of the work special consideration had to be given to some seven acres of swamp which was encountered. The underlying material of the swamp was a plastic clay. The method of treatment was to excavate all the loose top soil, and lay a grillage or foundation of paving stones, of a size which one man could lift, loose or small stony material being filled into the spaces and compacted. The concreting was laid directly on this paving; and the method adopted was so successful that when the concrete was dry a 50-ton locomotive was run over the surface without any detriment.

The filling of the reservoir commenced on October 26, and water was allowed to pass in slowly until the concrete floor and saddles over the pipe lines were covered for the winter. On March 13, there having been prior to this date a shortage of storage in the watershed reservoirs of the Croton, the water was allowed to pass freely into the basin until it had reached a level of 128.45 feet, which occurred on April 3. On April 9, after drawing 40 million gallons to replenish the depleted storage in Central Park reservoirs, the gates were closed, with the water standing at elevation 127.09 feet, which corresponds to 21.09 feet depth of water. On April 30, with an evaporation, etc., of about 0.017 of a foot per day, the reservoir stood at 127.08, thereby showing that the rainfall directly into the basin itself during these three weeks had about equaled the evaporation. The rainfall during this period was about 5 inches, and the evaporation, etc., about 4½ inches, which shows that the basin, considering the fact that it is new and has had but little time for silting action to take place, is a comparatively tight structure. Moreover, it is significant that in a few places, where water was observed seeping through the masonry when the water was first let in, the chemical action going on in the cement, and the silting effect of the water itself, are gradually sealing up even such slight leaks.

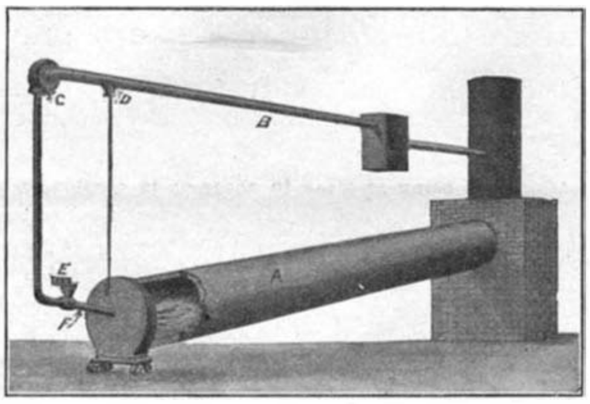
How to Make Concrete.

In determining the proportions of the aggregates and cement for a certain piece of work, it is necessary usually to take samples of the broken stone (or gravel) and sand which are most available to the site, and make measurements of the percentage of voids in the stone which must be filled by the sand, and the percentage of voids in the sand which must be filled by the cement. This is done by taking a cubic-foot box and filling it with broken stone in a thoroughly wet state. The box is then filled with as much water as is required to completely fill it in addition to the stone, which upon being poured off gives the relation between the volume of the voids and the volume of the stone. The required amount of local sand thus determined is then measured out and placed in the box with the stone in a damp state. Water is then used to determine the percentage of voids left in the sand, which gives the approximate amount of cement required, although an excess of cement is almost invariably used. Engineers everywhere differ regarding the best proportion to be used, but in general the above test, roughly made, will determine it well enough. The proportions which are most universally used are as follows: 1 cement, 2 sand, 4 broken stone; where extremely strong work is desired. Tests show that a 6-inch thickness of 1—2—4 concrete properly made is waterproof up to about 50 pounds to the square inch. This concrete is frequently used for facing dams. 1—3—6 is the proportion generally used for the interior of dams and large structures. It is entirely suitable for large foundations. 1—4—8 is frequently used for foundation work, and when properly mixed makes good concrete, although it is about the limit of what is considered good work, and would not be suitable for very important structures. 1—5—10 is equal to any concrete made with natural cement. It is a well-known fact that the volume of concrete when mixed with water is somewhat less than the volume of the aggregates and cement before mixing. The contractors' rule is that the volume of mixed concrete is equal to the volume of the stone plus one-half to one-third the volume of the sand.

There has been much discussion among engineers and others as to the amount of water that should be added to the aggregates and cement for making the best concrete; and while it is not the purpose of this paper to enter into this controversy, it might be said that the modern tendency is toward wet concrete. The old way was to add just enough water, so that when all the concrete was in the form and tamped, it would show moisture on the surface. The tamping is a very important part of the operation, and the quality of the work is dependent upon how well this is superintended, as unless it is well and thoroughly done the concrete is liable to be honeycombed and imperfect, especially near the forms. With the growth of the use of concrete the old method of putting it in the forms nearly dry and depending on tamping to consolidate it has been more or less abandoned, and the more modern way is to put the concrete in quite wet, as less tamping is required and much labor and expense saved. One of the great objections to this scheme is that if care is not taken, the water will tend to wash the cement from the stone and sand; in other words, unmix it. However, it may be said that it is now generally understood that rather wet concrete properly handled makes better work. The amount of water to be added to the aggregates and cement varies from 1 water to 3 cement by measurement to 12 per cent of water by weight. In 1887 Mr. Carey, of Newhaven, England, made the statement that 23 gallons water per cubic yard of cement was the best mixture. Quite frequently salt water is used in mixing concrete in cold weather to prevent freezing, and it seems to have no ill effects on the resulting mixture.—Cement Age.

THE IMPINGING FLAME IN CEMENT BURNING.

The use of the impinging flame in cement burning has come to be recognized as the best method yet devised for increase of output and economy of fuel. This principle, as put into practice under patents granted to Mr. Byron E. Eldred, has attracted the attention of cement manufacturers all over the country. In the Eldred process the air used to support combustion is modified by mixing with it a certain amount of waste stack gases of the kiln. The method of operation is shown clearly in the accompanying diagram. The waste gases are conducted through the pipe, *B*, by the exhaust fan, *C*. Air is then admitted at the opening, *D*, the amount of oxygen desired in the mixture being accurately controlled by means of dampers. The fan, *C*, discharges this mixture into the coal feeding apparatus, *E*, from which it goes through the pipe, *F*, into the kiln, *A*. The point, *F*, is so arranged with reference to the kiln that the hottest part of the tempered flame comes into direct contact with the material. One striking advantage of the process is the easy regulation of the mixture made possible by the manipulation of the damper at the air inlet, *D*. It is possible speedily to adjust the air mixture to meet conditions in the kiln; thus, when rings begin to form, an increase in the quantity of stack gases can be quickly made, which causes the removal of the mass. An experienced operator will have no difficulty with the Eldred method in obtaining a direct impingement of the flame and at the same time avoiding difficulties which formerly arose due to contamination of the discharging clinker. In using this process the cement company has been able to increase the output of each of its eight kilns about eight per cent, and to make a saving of about five per cent in consumption of fuel without causing any change in the quality of its product.



THE IMPINGING FLAME IN CEMENT BURNING.

Official Meteorological Summary, New York, N. Y., April, 1906.

Atmospheric pressure: Highest, 30.47; date, 3d; lowest, 29.44; date, 25th; mean, 29.98. Temperature: Highest, 74; date, 30th; lowest, 31; date, 1st; mean of warmest day, 64; date, 30th; coldest day, 40; date, 1st, 2d; mean of maximum for the month, 60.1; mean of minimum, 43.3; absolute mean, 51.7; normal, 48.7; average daily excess compared with mean of 36 years, +3.0. Warmest mean temperature for April, 54, in 1871; coldest mean, 41, in 1874. Absolute maximum and minimum for this month for 36 years, 90, and 20. Precipitation: 5.78; greatest in 24 hours, 2.42; date, 9th, 10th; average for this month for 36 years, 3.35; excess, +2.43; greatest precipitation, 7.02, in 1874; least, 1.00, in 1881. Snow: Trace; date, 9th, 23d. Wind: Prevailing direction, northwest; total movement, 9,712 miles; average hourly velocity, 13.5 miles; maximum velocity, 54 miles per hour. Weather: Clear days, 12; partly cloudy, 11; cloudy, 7. Thunderstorms, date, 21st, 30th.

The Current Supplement.

The current Supplement, No. 1584, is opened by B. S. Bowdish with an article on the Rapid Growth of Birds. An article on Artificial Gems will be of interest to the jeweler. Mr. James P. Maginnis continues his discussion of Reservoir, Fountain, and Stylographic Pens. A fourth installment of Valuable Alloys is published. Interesting to the naturalist is an article on the domestic life of animals. The well-known meteorologist, Prof. Cleveland Abbé, writes on the relations between climates and crops. A most ingenious piece of mechanism is described in an article entitled "A Speed and Mileage Recorder for Automobiles and Railroads." The Tangent Galvanometer and Its Construction is described.

THE ADVANTAGES AND LIMITATIONS OF REINFORCED CONCRETE.

(*Continued from page* 383.)

with the older materials. This condition must be charged in large measure to the fact that proprietary concerns have been chiefly instrumental in promulgating the use of the new material. Their purpose has not been that of true engineering to adopt the material only for such uses as it is particularly fitted, but that of the sales agent, to dispose of as much material as possible by forcing its use in every conceivable way. The natural result has been to see reinforced concrete used in many places where plain concrete would have served well enough, and in other places where every consideration called for the use of steel. The remedy for this evil will come with the passing of concrete-steel work into the hands of engineers whose only object is to employ the material best fitted for their purpose, be it whatever it may; and this transition has already begun. Another evil rising from the same cause and destined to be remedied in the same way is the tacit acceptance of empiricism as a rule of design. Already the theory of reinforced concrete is engaging the time and attention of many competent engineers, and a mass of reliable test data is being accumulated which will soon relegate empirical rules for reinforced concrete to the position they have long occupied in designing steel structures.

These strictures against empiricism will doubtless meet with opposition from some quarters, but they are entirely warranted. There is no place in engineering for guess-work whenever scientific determination is possible. It is becoming increasingly plain, moreover, that it is possible in reinforced concrete work. The common assumption of certain builders, that the laws, formulas, and methods of calculation used for ordinary materials cannot be applied to such a combination of two materials as is reinforced concrete, comes very close to being utter nonsense. The sooner such assumptions are banished from reinforced concrete work, the better it will be for the engineer and the building public; any attempt to weave a net of mystery about the new material is entirely wrong.

What Science Loses by the Earthquake.

Science has lost almost irretrievably in the destruction of one institution, not to refer to others, in which the most ardent hopes of the future were centered. The history of the California Academy of Sciences has many counterparts in other institutions devoted to pure science. It was begun forty years ago, and after a career of stress and poverty, at last as a beneficiary of the Lick estate, emerged into the full sunshine of wealth, and with splendid equipment was doing invaluable work in investigation and discovery. The latest expedition to be sent out by the institution is even now at work preparing a catalogue of the flora and fauna of the Galapagos Islands, where a company of scientists are exploring that remote group, and filling a gap which thus far has remained a blank page to science. In the department of entomology the academy has done immense service to general knowledge. Its collection of specimens was one of the finest in the world, and can never be replaced, and its museum of natural science, fossils, Indian curiosities, reptiles of California and Lower California, Aztec and Mexican, birds, together with a complete collection of the flora of the Pacific coast, included much that can never be replaced and many things that are lost to the world forever.

The Astronomical Society of the Pacific lost its valuable records and many rare manuscripts, as did the Geographical Society of the Pacific. The University of California, with its great museum temporarily housed at the Affiliated Colleges, suffered no loss from either shock or flames. Every public library in San Francisco fell a victim to the catastrophe, the largest being the Free Public with three branches containing 150,000 volumes; the Mechanics', with 80,000; the Mercantile, with 60,000; and the San Francisco Law, with 41,000; and the library of the California Historical Society, with its priceless manuscripts and unreplaceable records. There were in the city many noted private and professional libraries, which were all destroyed; no one had time to save books. Millions of volumes were reduced to ashes. Of schools and colleges destroyed, the most noted was St. Ignatius, a college of the Jesuit Fathers, located on Van Ness Avenue and the first established in San Francisco. The society also lost its magnificent church, built in the style of the Spanish Renaissance and richly decorated. College and church cannot be replaced for less than a million and a half dollars. Twenty-eight public schools of all classes were burned.