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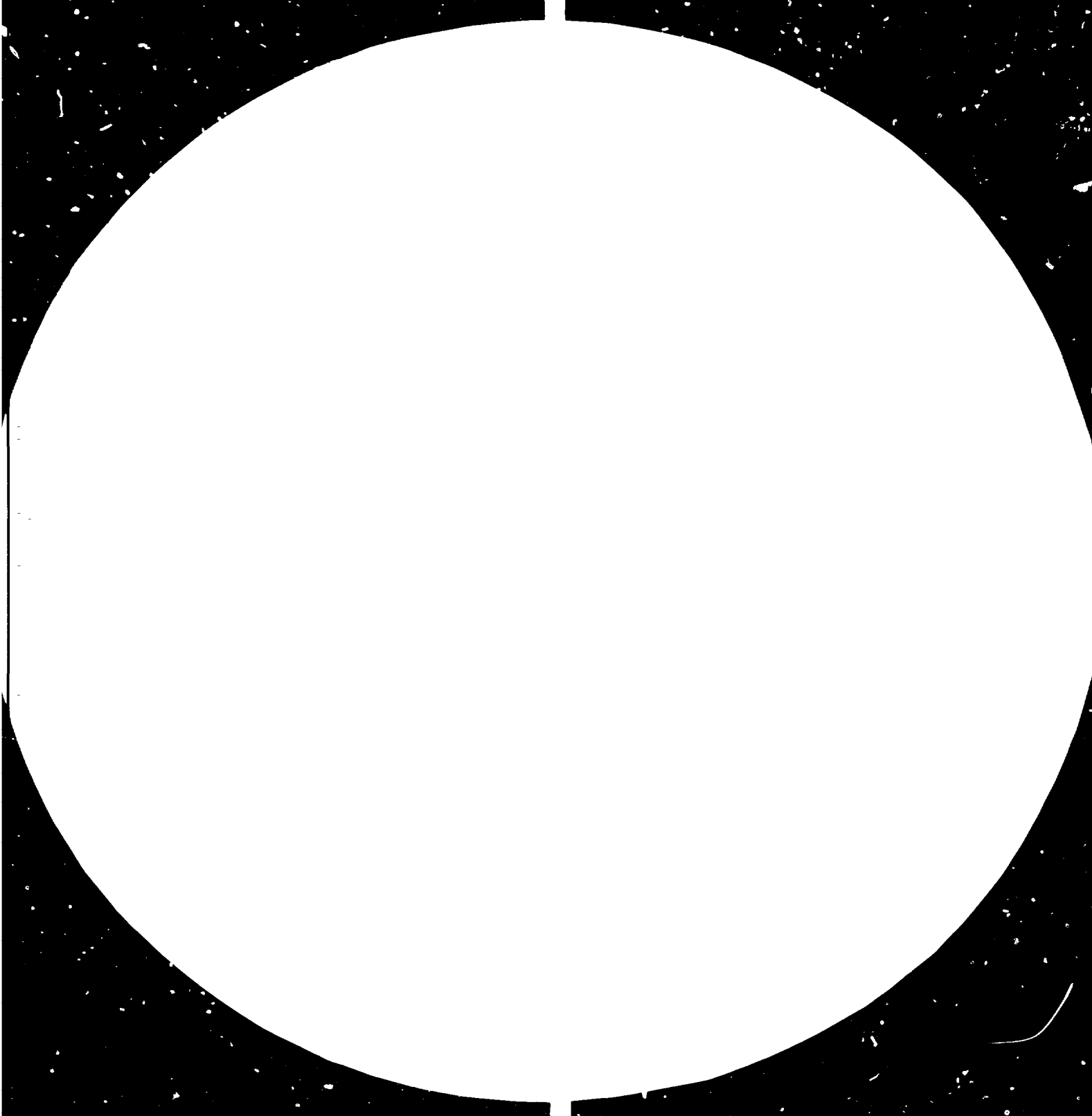

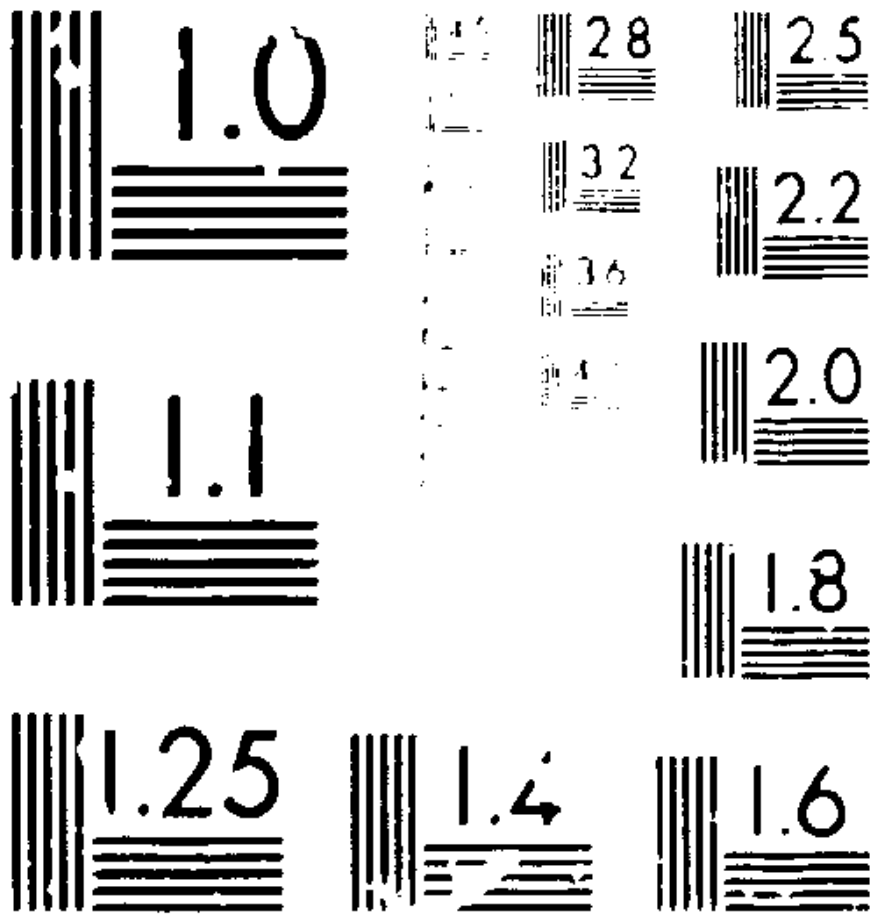

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THE GENERAL INTRODUCTION OF THE CEMENT AND CONCRETE PRODUCTS IN CHINA*

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1. Cement and concrete materials

1) Cement

China has quite a long history in developing its cement industry. As early as in 1889 its first vertical shaft Kiln was built in Tangshan by Qixin Cement Plant. In 1906 Qixin Cement Co. was set up and installed the first rotary Kiln with a capacity of 40,000 tpy.

The annual production of cement in 1949 was 660,000 tonnes. However, Chinese Cement Industry has been rapidly developed only after liberation. In 1979, the annual output reached 73.9 million tonnes, among which 24.72 million tonnes were produced by 49 big and medium-size cement plants with 135 rotary Kilns and 49.18 million tonnes by 3400 mini cement plants with vertical shaft kilns.

In 1979, average strength grade of clinker was No. 600 and that of cement was No. 500 (according to China National Standard for dry mortar) in big and mediumsized cement plants.

Regarding cement varieties, the proportion of different cement manufactured is as follows:

Ordinary Portland Cement	49.93%
Slag cement	41.40%
Pozzolanic cement	1.55%
Rapid-hardening cement	1.49%
Oil well cement	1.92%
Dam cement	0.83%
White cement	0.17%
Other cement	0.71%

Production processes, their output percentage and unit heat consumption of clinker are cited below:

Wet process	62.56%	1503.5 KCal/Kg.clin.
Semi-dry process	20.80%	1205.8 KCal/Kg.clin.
Dry process	16.64%	1506.7 KCal/Kg.clin.

The fuel for China's cement industry is mainly coal. Only a few cement plants use oil or natural gas as fuel. The proportion of different types of fuel used in cement industry is shown below:

Coal	88.28%
Oil	11.09%
Natural gas	0.63%

The utilization of industrial wastes for manufacturing cement is an important way for energy conservation. At present, about 300 million tonnes of waste slags are discharged by the industrial sector every year, in which 27 million tonnes are fly ash, 70 million tonnes colliery waste, 18 million tonnes blast furnace slag, 6 million tonnes steel slags, 50 million tonnes slags from municipal industry and households, and about 100 million tonnes of other waste slags such as tailings aluminium slag, calcium carbide sludge and so on. But the utilization ratio of these industrial waste slags is not high in our country. The utilization ratio of fly ash is about 10%, the ratio of blast furnace slag is about 70%, mainly for cement industry.

2) Concrete

The development of engineering and technique has set different requirements on the properties of cement and concrete products. Consequently, cement and concrete with special properties have thus been produced to meet various requirements.

China today has more than 60 types of cement, 20 of which are always manufactured for making various kinds of concrete and concrete products.

(1) high-early strength of cement concrete

The quick-hardening cement concrete is mainly made of tricalcium silicate-tricalcium aluminate, calcium fluoraluminate-calcium silicate, calcium sulphoaluminate-

calcium silicate, calcium aluminate and their four derived systems. For example, the quick-setting and quick hardening aluminate cement concrete has a compressive strength up to 200 Kg/cm^2 in one hour after cast, and 300 Kg/cm^2 in 3 hours. The compressive strength of another cement, the quick-hardening silicate cement, reaches 200 Kg/cm^2 in 4 hours after cast. The concrete produced with early strength sulphaluminate cement or aluminous cement has an applicable strength in 6 to 24 hours. In addition, the cement for sand mould, which is based on calcium fluoraluminate-calcium silicate, has been successfully used in machine building industry.

(2) Cement concrete for water works

Special cement used in the construction of dams and hydraulic structures is slag low-heat portland cement and pure portland cement. Owing to its low heat of hydration and scour durability and freeze thaw resistance, this type of cement has applicated for 30 years. The sulphate-resistant portland cement and high sulphate-portland cement concrete have yielded an excellent result when used in sea and tunnel works.

(3) Expansive and self-stressing concrete

Approximate ten types of various expansive, shrinkage-compensating and self-stressing cement concrete have been produced in China. The expansive cement chiefly includes:

The alunite expansive cement of silicate system and the gypsum alumine expansive cement of aluminate system which expand during the formation of calcium sulphate hydrate, and the pouring cement of silicate system which expands when the lime produces calcium hydroxide. They are respectively used for steel wires anchoring, anchor bolts fixing, machine base casting, leakage proof and jointing.

The self-stressing cement comprises silicate self-stressing cement, sulphoaluminate self-stressing cement and aluminate self-stressing cement which produce self-stressing in the formation of sulphoaluminate hydrate and is mainly used in making self-stressing concrete pipes. The self-stressing value of silicate self-stressing concrete pipes ranges between 20 Kg/cm^2 and 30 Kg/cm^2 whereas that of sulphoaluminate self-stressing concrete comes to 40-50 Kg/cm^2.

(4) Heat and fire resistant concrete

At present, China turns out approximately 20 types of concrete resistant to high temperature. Of these, there are alumina cement, low calcium content aluminate cement and aluminate concrete of fire-resistance. With these, refractory concrete product, plastic refractory materials and thermal insulating and heat resistant light-weight materials are produced and used by metallurgical, chemical, oil and cement industries in kiln lining. In addition, there is phosphate system's heat resistant concrete which used in high temperature and abrasion resistant lining and protective layer.

(5) Glass fibre reinforced concrete

Glass fibre reinforced concrete possesses a high bending, impact and tensile strength. Recently, we try to produce glass fibre reinforced concrete products by using ZrO_2 to change chemical composition of glass fibre to raise its alkaline resistance, lowering cement alkalinity and coating the glass fibre with organic matter. For instance, by adding an appropriate proportion of gypsum and coal ash to early strength sulphoaluminate cement, a glass fibre concrete is produced and applied in manufacturing composite external wall panels which is employed

in construction work.

(6) Steel fibre reinforced concrete

Concrete reinforced by short-cut steel fibre has excellent toughness and impact and explosive resistance. The trial-production of this material has been accomplished in China. Its compressive strength reaches 1000 Kg/cm^2 and the bending strength 150 Kg/cm^2, whereas the impact strength is 3 times over that of ordinary concrete. It is mainly used in special explosion and wear resistant engineering.

(7) Polymer impregnated concrete

Polymer impregnated concrete is of a composite material of organic and inorganic matter. The polymer impregnated concrete developed in China is impregnated in copoly impregnating liquid based on diyrene. This concrete has a superior strength and corrosion resistance. Its compressive strength ranges between 1200 and 1500 Kg/cm^2, crack strength 200-250 Kg/cm^2, bending strength 100-150 Kg/cm^2, and modulus of elasticity 5×10^5 Kg/cm^2. Also, it has excellent properties of akkaline and salt durability as well as impermeability and freezing resistance. It is chiefly used in special engineering, i.e., corrosion and abrasion resistant engineering.

(8) Aerated concrete and lightweight aggregate concrete

The production and application of aerated concrete go back to 1930 in this country. Since 1974, 26 aerated concrete plants have been set up, each of which has a capacity of more than 50000 m^3. By the end of 1979, the output of the whole nation had reached 700000 m^3. At present, China altogether has 33 aerated concrete plants and it's capacity has been reached to 2×10^6 m^3. Concerning the mix proportions of aerated concrete, we principally adopt the formula of cement, slag and sand. However, we have also studied the following formulas: cement, lime and sand; lime, cement

and coal ash; lime and coal ash; lime and tailing powder as well as cement and colliery spoil, etc. In addtion, study has been carried on the technique of reinforcement corrosion prevention and mass cutting. Owing to its low density, excellent heat insulation, easy workability and energy saving, the aerated concrete has been extensively used in industrial and civilian buildings. For example, aerated concrete blocks are used as bearing wall in 3-5 storey buildings, aerated concrete blocks and slabs in factory buildings, as well as large size aerated concrete panels assembled at jobsite are used in the multi-storey dwelling buildings.

In our country, research work for artificial lightweight aggregate was started in the 1950s. Several pilot plants were set up in the 1960s for trial-producing expanded clay aggregate, expanded shale aggregate and sintered fly ash aggregate. First sintered fly ash aggregate plant was put into action in 1967 and has been operating successfully from then on. At present, several large sintered fly ash aggregate plants are under construction. Sintered fly ash aggregate concrete has been widely used in dwelling buildings, cement boats, bridge deck and other works,

2. Cement and concrete products

1) Cement pressure pipe

China has trial-produced asbestos cement pipes, 3-stages prestressed concrete pipes, self-stressing cement pipes, one-stage prestressed concrete pipes, large diameter prestressed concrete pipes and short asbestos concrete well pipes for irrigation. For the aluminate self-stressing cement pipes and sulphate self-stressing cement pipes made of concrete at 1:2 of cement : sand, their self-stressing value can reach 60 Kg/cm^2, The rupture

pressure of cement pipes of diameter 800 and 300 mm reaches to 18 and 25 Kg/cm^2, respectively. The newly developed prestressed-self-stressing cement oil pipes of diameter 100 mm have a work pressure of 20 Kg/cm^2 and a rupture pressure up to 50 Kg/cm^2. Also, various types of self-stressing cement gas pipes of diameter up to 200 mm have been trial-manufactured.

As for the pipe manufacturing technology, we adopt 3-stage process, one-stage process, vertical vibration shaping method, core-mould with vibration method, roller-suspension technology, etc.

In order to use the integral types of pipe mould, a wax lining technique has been developed to render the demoulding operation very easy, China today has more than 180 cement pipes plants or shops, capable of making various types of cement pressure pipes of diameter 75-2200 mm, and with an annual productivity up to 3000 Kilometers.

Cement pressure pipes have been widely applied in urban water supply, oil and gas transportation, power irrigation and drainage, bittern transportation as well as ash discharging engineering. Cement pipes have been used widely in our country, because they have many advantages, such as saving in steel by 80% when replacing metal pipes, long service life up to 30-50 years, convenient construction, easy availability of raw materials and less investment.

2) Ferro-cement boats

From 1958, a year when the production of ferro-cement boats started, to the end of 1976, more than 100 types of ferro-cement boats were trial-produced in the whole nation, the total tonnage being up to 3200000, and more than 800000 tonnes of steel and 2.5×10^6 m^3 timber were thus saved. Today this country has 600 ferrocement boats manufacturing units with an annual capacity of 600000-700000 tonnage.

Ferrocement boats can be divided into 4 categories according to their usage:

(1) Farming ferrocement boats

In general, the length of a ferrocement boat does not exceed 15 m and its deadweight is under 15 tonnes. The main engine of a motor ferro-cement boat is under 40 HP. Forming ferrocement boats have the following types: irrigation and drainage boat, sludge dig boat, small power-generating boat, fertilizer boat, etc.

(2) Fishing ferrocement boat.

There are two types of fishing ferrocement boats: freshwater fishing boat and marine fishing boat.

The freshwater fishing boats work in rivers, lakes and reservoirs, in which the motor fishing boats have a 20-80 horsepower main engine. With respect to marine fishing boats, their length varies from 11.5 to 30 meters and their deadweight 5-100 tonnes, whereas the main engine of motor ones ranges between 80 and 300 horsepower.

(3) Transport ferrocement boat

This category comprises cargo boat, towboat, barges, passenger-cargo boat, bulk cement transport boat, water supply boat, cold storage boat as well as ferry boat,

China has built 3000 tonnes coastal cargo boats, 1320-horsepower towboats and 600 horsepower passengercargo boats of 500 seats.

(4) Working ferrocement boat.

Here, working ferrocement boats mean those conducting special jobs in water, such as storage boat, crane boat, pumping boat, pile driving boat, light boat, dormitory boat, floating dock, marine drilling boat, etc.

This country has built 10000 tonnes reinforced concrete floating docks, and marine drilling boat, etc.

This country has built 10000 tonnes reinforced concrete

floating docks, "Luehan" of which has 158.145 m of total length, 33.60 m of total width and 14.170 m of total height with a lifting power of 6500 tonnes.

The merit of ferrocement boat is saving in steel and timber, generally speaking, it can save 50% steel or 80% wood as compared with a steel boat or a wood boat. In addition, it is superior with respect to corrosion resistance, durability, easy maintenance and repair, etc.

3) Concrete railway sleeper

Today our country has a capacity of 5,000,000 to 6,000,000 concrete sleepers. From 1958 to 1978 the total accumulated output of concrete sleepers came to more than 52850000 pieces for 24000 Kilometers railway.

At present, the country has 17 concrete sleepers manufacturing plants holding 22 production flow lines. The 2 x 5 combined moulds are employed in these plants and 10 sleepers are shaped on a 1 x 5 combined vibrating base at a time and conveyed on roller arrangement. The annual output of a large sized plant reaches 5×10^5 to 1×10^6 sleepers whereas that of a medium or small sized plant ranges between 1.5×10^5 and 4×10^5 sleepers.

Of these, the Puntai Bridge Girder Plant located in the south-eastern suburb of Peking produces concrete railway sleepers. The strength of the concrete is 500 Kg/cm^2, the cement content is 410 Kg/m^3, w/c=0.35, cement:sand:gravel=1:1.54:3.2. The sleepers are loading-vibrated at a frequency of 3000 cycles/minute for 150 seconds, and cured without pressure at 90-95°C for 7-8 hours. The relaxation strength is 350 Kg/cm^2. The annual output is 1×10^6 sleepers corresponding to 99000m^3.

4) Concrete pole and pile

Concrete pole for lighting and power transmission has a superior bearing strength and durability over that of timber poles. Our country began to produce common reinforced concrete

poles with centrifugal shaping process in the 1950s and to produce prestressed concrete pipes in 1960s. The latter have higher crack resistance, rigidity and durability, lower reinforcement percentage and lower cost. At present, most of the plants in this country employ ϕ 5 carbon steel wires ($\sigma_b \geq 150$ Kg/mm^2) as reinforcement of poles and anchorage ends of reinforcement are formed with cold upsetting. The strength of poles when demoulded is not under 300 Kg/cm^2 and the 28-day strength is not less than 400 Kg/cm^2. In respect to the length of poles, there are seven, i.e, 7.0, 8.0, 8.5, 9.0, 10.0, 11.0, and 12.0 meters. The large diameter varies from 263 to 350 mm and the wall thickness of all poles is 35 mm. The poles have 9-18 wires of main reinforcement (ϕ 5) and selfweight of 400 - 780 Kg each one, and embedded depth of their bottom and in ground would be 1.5-2 m.

There are two types of shaping for concrete piles, namely, vibrating shaping and centrifugal shaping. The prestressed concrete pile has an advantage of high impact resistance, saving in steel and reduction of cost. The length of piles is 8 and 10 m with exterior diameter 400 and 500 mm corresponding to 240 and 390 mm of interior diameter. The centrifugal shaped concrete piles have a strength of 450 Kg/cm^2 in 28 days and R360=600-700 Kg/cm^2. The standard strength (ϕ12)of the main reinforcement of concrete piles in 6500 Kg/cm^2 and the effective prestress value of the concrete comes to 50 Kg/cm^2.

5) Asbestos cement products

China has a rich asbestos resource, however, the annual output is only 120000 tonnes. Today, this country possesses 60 units which produce asbestos cement shingles (or sheets) with a productivity up to 40 X 10^6 m^2. But at present the annual output is no more than 20 X 10^6 m^2.

There are approximately 70 asbestos cement pipes manufacturing units with a capacity of more than 8000 standard kilometers, but the output in 1978 is only 1800 standard Kilometers.

Our country began making asbestos cement pipes in 1954, adopting wet process, semi-wet process and dry process (roller suspension process). According to their specifications, asbestos cement pipes are divided into industrial and agricultural pipes. The industrial pipes include water pipes, bittern pipes, gas pipes and oil pipes, which are 75-279 mm in diameter and 4-5 m in length. They are also divided into low pressure pipes (4.5 Kg/cm^2), medium pressure pipes and high pressure pipes (10 Kg/cm^2). The agricultural pipes include well pipes and pressure pipes. The diameter of well pipes ranges between 189 and 300 mm, and the length 2 to 4 m. The agricultural pressure pipes have 4.5 Kg/cm^2 working pressure and used in water pumping and sprinkling irrigation.

6) Prefabricated concrete products

China has more than 1000 prefabricated concrete components plants with a capacity of $7 \times 10^6 - 8 \times 10^6$ m^3. They can produce various types of concrete components, i.e., beams, slabs, columns, pipes, piles, poles, etc.

Referring to shaping technology, the following have come into being in recent years:

The vaccum dewatering technology, wall panels and floor slabs production lines, cirdular production lines for medium sized blocks, pull-out core with vibration for hollow slab, lift form, push-pressure extrusion method and the production lines with the combination of shaping and curing (i.e. tunnel kiln, vertical kiln and "⌒" shape kiln). As for the curing technology, there are following processes:

deep pit curing, kiln body curing, hot mix with hot mould, infrared ray curing, solar energy curing, dry heat curing and wet heat curing, etc.

Admixitures, especially water-reducing agents, have been applied more commonly in the production of cement products and concrete components. Just like the prestressing technology, the water-reducing agents have become an important factor in improving properties of cement products. From the 1950s on, our country has begun using pulp waste as a plasticizing agent, and later on waste-molasses as a water-reducing agent. In the 1970s the advances of concrete construction technology gave a boost to the research and production of water-reducing agents. China today has developed approximately 10 types of water-reducing agents, among which lignosulphonic acids and their salts, NNO of sale of naphthalinesulfonic acid and its derivaties, MF, Bl, NF and ONF, etc., are of superior properties. In addition, there are melamine, epoxy resins, humic acid sulphated taw, etc. Addition of water-reducing agent of 0.2-1.5% weight of cement can reduce the mixing water content by 5-25% when keeping the workability constant, or increase the slump by 10-20 cm when keeping w/c ratio constant, or decrease the cement content by 5-20% when keeping the concrete strength constant. Also, special concrete and its products with different properties can be made with different types of water-reducing agents.