At present, the materials used for conveying water and sewage are cast iron pipes, steel pipes, RCC pipes and stoneware glazed pipes. Though in general they are satisfactory, in certain conditions they suffer from brittleness, lack of resistance to corrosion and chemical attack. The most common material used for conveying sewage and in the construction of sewage treatment plants, is cement concrete; but it is not found to be an effective material for this purpose. The role that polymer concrete can plays not only in an effective distribution system, but also in the sewage treatment plant, will be of paramount importance; particularly, in the construction of sludge digestion tanks used to generate gas for much needed power generation.

It has been reported that non-reinforced PIC pipes are 20% stronger than reinforced unimpregnated pipes, and also that PIC pipes can withstand twice as much Hydrostatic pressure as that of the unimpregnated reinforced pipe.

In spite of the accute shortage of steel for industrial progress in developing countries, structural steel is widely used in the construction of industrial buildings, workshops and bridges. This unproductive use of steel in the construction of industrial structures is perhaps, due to lack of efficient, alternative material. Polymer concrete technology will provide a good substitute for structural steel in these situations, thus releasing more of this precious material for production purposes.

USE IN IRRIGATION STRUCTURES

Agriculture is still the backbone of the economy of many a developing country. In fact, a considerable amount of foreign exchange reserves is spent on the import of foodgrains. In their endeavour to maximise agricultural production, it is essential for them to extend the service of old irrigation structures; increase the height of the existing dams and anicut; and build new dams. In all the above works, the use of polymer, polymer concrete and polymer mortar will be of immense help.

Further, millions of cubic metres of precious water is being lost due to seepage, while conveying it through canals. The lining of these canals with conventional concrete, reduces seepage losses to some extent, but its performance can be still greatly improved, by adopting polymer impregnated concrete.

The application of polymer concrete technology can also find wide application in many ancillary irrigation works, such as, spillways, divertion tunnels, and apron to withstand the disruptive cavitational action of flowing water.

USE IN FERROCEMENT PRODUCTS

If self-sufficiency on the food front is to be achieved, the preservation of agricultural output is as vital as its production. The World Health Organisation's report has stated that in India, rats destroy food stuff worth one thousand million dollars per year, due to inadequate storage facilities.

It is also equally important for developing countries to exploit the vast resources of sea food and develop fishery as an industry. This would mean deployment of a large number of cheap and durable, fishing trawlers and boats.

Ferrocement technique is an up and coming one, which can be used to construct cheap and durable food grain storage silos, as well as for sea-going fishing trawlers. In fact, the National Science Academy, Washington, in one of their recent booklets have advocated the use of ferrocement for construction of food grain silos, long term seed storage silos, and similar utility items at village levels.

This ferrocement technique is already being used in the developing countries for the manufacture of boats, fishing trawlers, domestic overhead water tanks, grain and seed storage silos, manhole cover and cow dung gas plants. Ferrocement generally being thin is liable to corrode due to environmental factors.

Since there is abundant scope for the adoption of ferrocement products on a mass scale, its manufacture could be industrialised in the developing countries. The application of polymer impregnation technique to ferrocement products will result in the improvement of desirable properties like strength, imperviousness and resistance to corrosion.

USE IN CONNECTION WITH POWER GENERATION

Power is the problem of both developing countries and the developed countries. With continuous industrialization in the former countries, the demand for energy has always outstripped its generation. The energy crisis has become all the more acute with the price hike of oil, by oil-producing countries. In a country like India, the per capita power consumption is only 71 KWH as compared to 6550 KWH in a country like U.S.A. In many other developing countries the per capita consumption is still lower than India. Thus, there is a great need to generate more power in order to meet growing demands.

Most of the developing countries do not have large natural resources of coal for thermal generation or enough water resources for hydroelectric power. Hence, they are forced to resort to nuclear power generation. Concrete is one of the materials used these days in the construction of container vessels in nuclear power generators, on account of its good radiation absorption quality, strength and durability, even in adverse conditions. The use of Polymer Impregnated Concrete in conjunction with heavy weight concrete will lend many advantages to the existing practices. Another alternate problem with nuclear power generation, is the storage of used radio active fuel rods without incurring any pollution risks. It is here again that the use of PIC containers may be of unquestionable value.

USE IN MARINE WORKS

Those developing countries, with long coastal belts are required to give particular attention to the development of their coastal area, for further economic gains. The requirement for this development, may be, expansion of the naval arms, construction of docks and harbour, development of fisheries, off-shore drilling for oil exploration and transportation through sub-marine pipelines, prevention of coastal erosion, expansion of communication systems, or for recreational purposes.

In the absence of any other suitable material, concrete is one of the extensively used materials of construction in marine works. Though over the years, admixtures and additives are being used to increase the durability of the concrete, still conventional concrete has not been able to satisfactorily withstand the aggressive nature of sea water and the abrasive and leaching action of waves.

PIC, possessing high surface hardness, very low permeability and greatly increased resistance to chemical attack, adds a new dimension to the field of marine construction works for coastal development.

USE IN DESALINATION PLANTS

Desalination of sea water is being resorted to, in order to augment the shortage of surface and ground water in many developing countries. The material used in such works has to withstand the corrosive effects of distilled water, brine and vapour, at a temperature upto 143°C. Carbon steel vessels which are currently in use, are comparatively costly and deteriorate after prolonged use. Preliminary economic evaluation, has indicated savings in construction cost over that of conventional concrete, by the use of PIC.

USE IN PRESTRESSED CONCRETE

Prefabricated prestressed concrete is becoming popular but, further development in this field, is hindered by the inability to produce ultra high strength concrete compatible with the improved high tensile steel, which is presently available for prestressing purposes. Since PIC exhibits a very high compressive strength, of the order of 1000 to 1400 kg/cm^2, it can be used for prestressed concrete, for the construction of industrial structures, and long span bridges. Coupled with these are the advantages of low creep characteristics; and a high level of imperviousness makes it an ideal material for prestress concrete work.

MISCELLANEOUS USE

PIC may also provide a permanent solution for durable flooring in tanneries, chemical factories, dairy farms, food processing units, and in many other situations where strength, chemical inertness and impermeability are required.

CONCLUSION

Developing countries, particularly those in the take off stage are investing large shares of their annual budget in constructional activities to achieve progress in various field. Because of the sheer volume of work, even a small saving or benefit, accruing directly or indirectly, on a short or long term basis, will make a tangible contribution to overall progress. Some of the situations where polymer concrete technology can be applied, have been briefly described. However, it should be remembered that application of polymer concrete is not a "Cure" for all situations. It should be adopted only under such conditions where benefit to cost ratio, can amply justify its use.

While advocating the application of polymer concrete technology, it should not be forgotten that sufficient technological skill and development of other infrastructures, is a primary pre-requisite. In fact, this is true in case of the adoption of any new technology. Self sufficiency in the production of monomers; perfection of polymerisation techniques in different conditions; training of competitive engineers and techniciane are a few of these pre-requisites.

Keeping in view the tremendous fillip that this innovative technique is likely to give to all round progress of the developing nations, developing or borrowing this technology, from whatever source available will be extremely worthwhile. It has also been lately recognised that preservation of world peace lies in uplifting developing countries and many a technologically advanced country has been extending a helping hand in this regard. Thus a rapid transfer of Polymer Concrete Technology from developed to developing countries may mean much, as it touches the fundamental progress of less advanced nations.

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SP 58-12

Experimental Study of a Process for Manufacturing Extremely High Strength Concrete

By Toshio Fukuchi and Yoshihiko Ohama

Synopsis: The objective of this study was to find an appropriate process for manufacturing high-strength concrete. The high-strength concrete is produced by a combined process involving mixture with a semi-polymeric water-reducing agent, autoclaving, and modification by polystyrene. Also the reporducibility of the compressive strength development was investigated.

It is concluded that concrete having a compressive strength of 2240 to 2490 kgf/cm^2 (32,000 to 35,000 psi) (220 to 244 MPa) can be prepared by this combined process with good reproducibility.

Keywords: autoclaving; compressive strength; high strength concretes; impregnating; polymer concrete; polystyrene; water reducing agents.

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INTRODUCTION

Recently, great interest has been focused on development of high-strength concrete with significant advance of building engineering.

It has been described in many papers that, generally, high-strength concrete is manufactured by the following processes:

(a) Mixture proportioning with water-reducing agents

(b) Mixture proportioning with active aggregate

(c) Modification by polymers

(d) Fiber reinforcements

(e) Press molding

(f) Autoclave curing

However, high-strength concrete having compressive strength of 2000 kgf/cm^2 or more has not been developed until now in Japan.

In this paper, the manufacturing process for high-strength con-concrete, based on the combination of Processes (a), (c), and (f) as stated above, is discussed and its compressive strength of 2000 kgf/cm^2 or more is achieved.

MATERIALS

1. Cement, Aggregate, and Admixture

Normal portland cement, Hatsukari crushed andesite (size < 20 mm) and Kinugawa river sand (size < 2.5 mm) were used for the preparation of concrete as a base material. Their properties were listed in Tables 1 and 2. Also silica powder (purity 99.7 percent, specific gravity 2.63, size < 44μ) and semi-polymeric water-reducing agent were used as admixtures for the mixture proportions of concrete.

2. Monomer, Crosslinking Agent, Catalyst, and Coupling Agent

Styrene monomer, $(CH{=}CH_2)$ for industrial use, trimethylol-propane trimethacrylate (TMPTMA) as a crosslinking agent, α, α'-azobisisobutyronitrile (AIBN) as a catalyst, and silane-type coupling agent (SLN) were used for impregnation.

TESTING PROCEDURES

1. Preparation of Specimens

(1) Preparation of Concrete as a Base Material

Concrete was mixed according to the mixture proportions given in Table 3. Specimens of Ø7.5 x 15 cm were molded in accordance with JIS A 1132 (Method of Making and Curing Concrete Specimens) and then precured at 20 C, 80 to 90 percent R.H for 24 hr. Immediately after precuring, they were cured by autoclaving at 180 C and 10 atm. Then they were heat-treated at 200 C for 24 hr.

(2) Polymer Impregnation

The heat-treated specimens were evacuated to 1 mm Hg or less (133Pa) at ambient temperature for 1 hr and soaked in a styrene + TMPTMA mixture with AIBN and SLN under pressure for 9 hr for impregnation. Then they were placed in hot water of 80 C for an appropriate time for heat polymerization, and allowed to cool.

2. Compressive Strength Test

The polymer-impregnated and unimpregnated specimens were tested for compressive strength in accordance with JIS A 1108 (Method of Test for Compressive Strength of Concrete).

TEST RESULTS AND DISCUSSION

The test results are shown in Fig. 1 and Tables 4 and 5. Here the strength improvement factor (α) is expressed as follows:

$$\alpha = \frac{\sigma_i}{\sigma_o}$$

where
σ_i = strength of polymer-impregnated concrete
σ_o = strength of unimpregnated concrete

Polystyrene-impregnated autoclaved concrete having high compressive strength of 2000 kgf/cm^2 or more is obtained by the mixture proportions of Mix No. 6, No. 10, and No. 11 in Table 3. Generally speaking, the compressive strength of polystyrene-impregnated and unimpregnated autoclaved concretes tends to increase with an increase in the cement content and silica content, and with a decrease in the water-cement ratio in the mixture proportions of concrete. At the same cement content, the strength improvement factors (α) of polystyrene-impregnated autoclaved concrete are much the same, regardless of water-cement ratio and silica content. Polystyrene-impregnated autoclaved concrete made of higher compressive strength concrete (base material) does not always give higher compressive strength. Also its compressive strength is hardly influenced by polymer loading.

In "samples" of 19 to 20 specimens of polystyrene-impregnated autoclaved concrete, the reproducibility of its compressive strength is successful.

Finally, in comparison with the compressive strength of polymer-impregnated autoclaved concretes obtained by other researchers, it is found that the compressive strength of polystyrene-impregnated autoclaved concrete using normal portland cement, developed by the authors, is the highest value in the field of super high-strength concrete studies.

CONCLUSIONS

The conclusions obtained from the above-mentioned test results are summarized as follows:

(1) Concrete having a compressive strength of 2240 to 2490 kgf/cm^2 is prepared by the combination process of mixture proportioning with semi-polymeric water-reducing agent, autoclave curing, and modification by polystyrene.

(2) In preparing the concrete, the reproducibility of its compressive strength is successful.

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