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Citation	Proceedings of the Thirteenth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-13), September 11-13, 2013, Sapporo, Japan, E-5-4., E-5-4
Issue Date	2013-09-12
Doc URL	http://hdl.handle.net/2115/54364
Type	proceedings
Note	The Thirteenth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-13), September 11-13, 2013, Sapporo, Japan.
File Information	easec13-E-5-4.pdf



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THE ROLE OF EXPANDING ADMIXTURE IN THE DEVELOPMENT OF STRENGTH OF PREPACKED CONCRETE

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ABSTRACT

Prepacked concrete is a special type of concrete which is different from the normal concrete in a number of ways. In this concrete, the coarse aggregates are first placed into the formwork and subsequently cement-based grout, usually with admixtures, is injected to fill the spaces between the coarse aggregates. This paper highlights the influence of chemical admixture, particularly the effectiveness of expanding agent in the development of strength of prepacked concrete at different ages of 7, 28 and 90 days. Along with prepacked concrete, normal concrete specimens having same water-cement and aggregate-cement ratios were made and tested under the same condition to evaluate the comparative behavior of strength development. It has been found that the overall compressive strength of both types of concrete with superplasticiser were higher than in concrete without any admixture. Expanding admixture, however, had been shown to have excellent performance in developing both compressive and tensile strength, as it provided better contact through expansion as well as through reduction in water-cement ratio in the grout.

Keywords: Prepacked concrete, admixture, expanding agent, compressive strength, tensile strength.

1. INTRODUCTION

Prepacked concrete as the name implies, derives its name from the unique placement method by which it is made. Unlike normal concrete construction, it is made by first placing the coarse aggregate in the formwork and then injecting a grout of sand, cement and water to fill the voids between the aggregate particles. Other names commonly given to prepacked concrete are preplaced-aggregate concrete, grouted concrete, colcrete and Prepakt – a trade name.

The method of preparing prepacked concrete has proved particularly useful in a number of applications like underwater construction, concrete and masonry repair, situation where placement by usual methods is extremely difficult, mass concrete where low cement content and low heat of hydration are required, and tunnel and sluiceway plugs to contain water at high pressure where very low shrinkage is important (King 1959). It is also useful in the manufacture of high density concrete

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for atomic radiation shielding where steel and heavy metallic ores are used as coarse aggregate (Taylor 1965).

Prepacked concrete is essentially a two-stage concrete; it differs from normal traditional concrete not only in the method of placement but also in that it contains a higher proportion of coarse aggregate. It may be regarded as 'skeleton concrete' as the coarse aggregates effectively rest against one another and the remaining voids are filled with cement mortar. Because of the inherent differences in the composition and structure, the strength properties of prepacked concrete are expected to be somewhat different from those of conventionally placed concrete. Either by experiment or by theory the strength behavior of prepacked concrete has been described in different ways. Some reports it to be stronger than normal concrete but others claim it to be weaker. At the same time there are conflicting reports regarding its rate of development of strength (Chefdeville 1963; Davis 1960; Taylor 1965).

Both chemical mineral admixtures of various kinds have been used in the manufacture of prepacked concrete. Grout fluidifier meeting ASTM C937-10 is commonly incorporated in the grout mixture to offset the effect of bleed water as well as to reduce the water cementitious material ratios. Limited amount of calcium chloride meeting the requirements of ASTM D98-05 has been used occasionally to promote early strength development. Water reducing and retarding admixture has also been used successfully in the grout. However, high-range water reducing admixtures (superplasticizers) appear to be potentially useful in the manufacture of prepacked concrete (Abdelgader 2008; ASTM C494-05; Awal 2002).

Along with high range water-reducing admixture, admixture having expansion properties have been used in normal and prepacked concrete (Manzel 1943). Expanding admixture, mostly consisting of aluminium powder generates hydrogen gas, which causes expansion of the grout while fluid, and leaves minute bubbles in the hardened grout. The aluminium powder, having a normal dosage of 1 percent by weight of cementitious material is consumed in the reaction, leaving a little or no residual metallic aluminium.

Both fly ash and natural pozzolans conforming to ASTM C618-12 are used in prepacked concrete construction. However, class F fly ash has been used in the great majority of installations since it improves the pumpability of the fluid grout and extends grout handling time (ACI committee 304). Other admixtures like class C fly ash, slag and silica fume have been employed in the grout, but data on their performance are quite limited.

This paper focuses the influence of chemical admixture, particularly the effectiveness of expanding agent in the development of strength of prepacked concrete. To obtain a comparative picture of strength development, normal concrete specimens having the same water-cement and aggregate-cement ratios were also made and tested under the same condition.

2. EXPERIMENTAL METHODS AND MATERIALS

2.1. Materials

The two basic constituents in the manufacture of prepacked concrete are coarse aggregate and grout. The choice of coarse aggregates, however, is of great importance. The coarse aggregate used in this experiment was angular and irregular basalt with a maximum size of 38 mm. The minimum size of coarse aggregate was, however, limited to 13 mm. Like that of coarse aggregate the grading of fine aggregate is critical with regard to the workability of grout. The fine aggregate used in the manufacture of grout was natural beach sand with 100 percent passing B.S. Sieve No.14 and with a fineness modulus of 1.7. The cement used throughout the study was ordinary Portland cement. The grading of fine and coarse aggregates used in this study is shown in Figure 1.

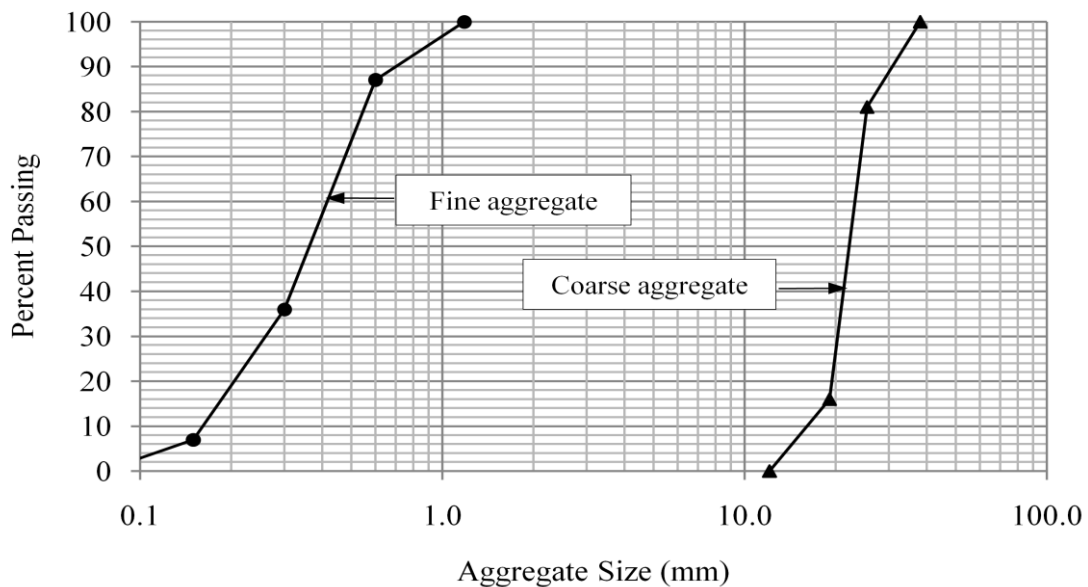


Figure 1: Grading of fine and coarse aggregates.

Two types of admixtures were used in this investigation: superplasticiser and expanding admixture. The superplasticiser added in the grout was a naphthalene-formaldehyde derivative of trade name 'Superplasticiser-C', and was mixed at the rate of 1.25 percent by weight of cement. The expanding agent, of trade name 'Injectacrete' was an aluminum powder based admixture which was used at the rate of 1 percent by weight of cement. The details of the materials used and the method of preparation, however, have been described elsewhere (Awal 1991; Awal 2002).

2.2. Manufacture and preparation of prepacked concrete specimen

In the manufacture of prepacked concrete, grouting of aggregate mass can be done either by gravity penetration or by injecting the grout at the base of the formwork so that it moves upward through

the voids between the aggregate particles. The test specimens in this study were obtained from the 150 mm diameter concrete column made for each mix proportion following the injecting method.

About one week after grouting, each 2000 mm high prepacked concrete column was sawn into cylinders of standard length of 300 mm by a diamond-impregnated circular saw. Until capping and testing, all the cylinders were wrapped in water-proof polythene sheets to prevent evaporation of water from them. Plaster was used to cap the cylinders before testing. For each mix series, equal number of normal concrete cylinders were cast, cured and capped in the same manner.

2.3. Casting of normal concrete

It is mentioned that along with prepacked concrete, normal concrete was also made to compare its strength behavior. In fact, it is very difficult to compare prepacked concrete directly with normal concrete not only due to its method of placement but also because of its different mix proportions. However, several trials were made to design a mix for normal concrete keeping water-cement and aggregate-cement ratios the same as in prepacked concrete, because water-cement ratio and aggregate-cement ratio are the two basic factors that largely govern the strength of concrete. The selected mix proportions, as calculated, are given in Table 1.

It is important to note that water-cement and aggregate-cement ratios in both the two mixes were kept constant. The only difference was in coarse aggregate to fine aggregate ratio. The higher percentage of sand in normal concrete indicates that instead of point-to-point contact as in prepacked concrete the coarse aggregate are floating independently in the mortar matrix.

Table 1: Typical mix proportions for normal concrete and prepacked concrete

Materials	Prepacked Concrete	Normal Concrete
Coarse Aggregate (kg/m ³)	1410	1185
Fine Aggregate (kg/m ³)	565	790
Cement (kg/m ³)	375	375
Water (kg/m ³)	187	187
Superplasticiser (l/m ³)	4.61	4.61
Expanding Agent (l/m ³)	3.75	3.75
Water/Cement	0.5	0.5
Total Aggregate/ Cement	5.25	5.25
Coarse Aggregate/ Fine Aggregate	2.5	1.5

2.4. Test series

In order to investigate the effect of different types of admixture on strength properties of concrete the experimental work was divided into three mix series. No admixture was used in Series-I. Superplasticiser was employed in Series-II, and in Series-III expanding admixture was used. To establish a suitable water-cement ratio for intrusion grout using cement, sand, water and admixture, several trial mixes were made in the laboratory. The major criteria adopted to maintain the uniformity of grout was its consistency, expressed as 'flow-factor' which is the time in second required to discharge a specified volume of grout from a flow cone. Using trials, a water-cement ratio of 0.52 with a flow factor of 25 was found to be suitable for pumping of grout without any admixture (Series-I). Corresponding to this flow factor, the water-cement ratios obtained for grouts using superplasticiser (Series-II) and expanding admixture (Series-III) were 0.45 and 0.47 respectively. Properties of grout for different mix proportions are summarized in Table 2.

Table 2: Effect of admixture on properties of grout

Test Series	Admixture	Sand-Cement Ratio	Water-Cement Ratio	Bleeding (%)	Sedimentation (-) or Expansion (+) (%)	Density (kg/m ³)	28- day Compressive Strength (MPa)
Series I	None	1.5	0.52	10.3	-1.3	2114	29.5
Series II	Superplasticiser	1.5	0.45	9.0	-0.7	2128	35.1
Series III	Expanding Admixture	1.5	0.47	7.1	2.6	2104	20.7

3. RESULT AND DISCUSSION

The investigation of strength of concrete for all mixes was carried out at different ages of 7, 28 and 90 days. The test results on compressive strength and tensile strength are presented and discussed in the following sections.

3.1. Compressive strength

Test data on compressive strength of prepacked concrete as well as of normal concrete are listed in Table 3. It has been stated earlier that no admixture was used in Series-I. The most significant finding in this series was the rate of development of strength. Data presented in the table reveals that the 7-day compressive strength of prepacked concrete was 17.9 MPa (23.5 MPa in normal concrete) which at 28 days was 28.9 MPa (32.8 MPa in normal one) and at the age of 90 days the compressive strength of both the concretes were almost equal. From the nature of development, it seems that the strength of prepacked concrete initially develops more slowly; at 7 days it was much

weaker, at the age of 28 days the rate of development was quite reasonable that continued to gain strength at later age.

'Superplasticiser-C', a naphthalene-formaldehyde derivative was used in test Series-II. Using this admixture in the grout the overall compressive strength of prepacked concrete was found to be higher than in Series-I. The possible reason for the increase in strength was due to higher fluidity of the grout achieved by using superplasticiser at a lower water-cement ratio. The water-cement ratio, for example, used to grout prepacked concrete in Series-I was 0.52 while a ratio of 0.45 was used in Series-II. However, this is to note that in developing strength this type of admixture seems to be more effective in normal concrete than in prepacked concrete. Although the overall compressive strength of prepacked concrete was increased as compared to the development in Series-I, compared to normal concrete within Series-II the compressive strength of prepacked concrete did not increase significantly. Table 3 also reveals that using superplasticiser the compressive strength of prepacked concrete was slightly lower than that of normal concrete at all ages. The possible cause for this lower strength of prepacked concrete in this series might be associated with the bleeding of water in grout as observed through a transparent cylinder tube. This was also evidenced by the loss of mortar-aggregate bond underside of aggregate particles on examination of the fractured specimens. The loss of bond in normal concrete, on the other hand, was found to be much lower.

Current literature and the preliminary investigation carried out in this study suggest that the quality of prepacked concrete depends not only on the strength of grout but also on its ability to expand while a fluid and remove the traces of bleed water that collect underside the aggregate particles. This has been reflected in the properties of grout, shown in Table 2. Although the strength of grout containing expanding admixture was found to be lower than that of other mixes, higher expansion with lower bleeding characteristics has been marked for the development of strength in prepacked concrete. It was with this idea that an expanding admixture – a blend of metallic aluminum powder expansion agent was used in the grout. The strength data shown in Table 3 reveals that using the expanding admixture the compressive strength of prepacked concrete was significantly increased. The compressive strength of prepacked concrete without any admixture, for instance at 28 days, was 28.9 MPa while incorporating expanding admixture the compressive strength increased to 42.3 MPa at the same age. The higher strength obtained in prepacked concrete was obviously due to the expanding behavior of the admixture used in the grout which maintained the solids in suspension thereby minimizing the loss of mortar- aggregate bond. A schematic representation of the settlement of grout underside of coarse aggregates particles is illustrated in Figure 2.

In normal concrete, however, the situation was different. Although the water-cement and aggregate-cement ratios were kept constant in both prepacked and normal concrete, using expanding admixture the compressive strength of normal concrete was found to be much lower than that of prepacked concrete. As there was no restraint to expansion in normal concrete, the generation of hydrogen gas led to an increase in the amount of voids with a consequent reduction in compressive strength.

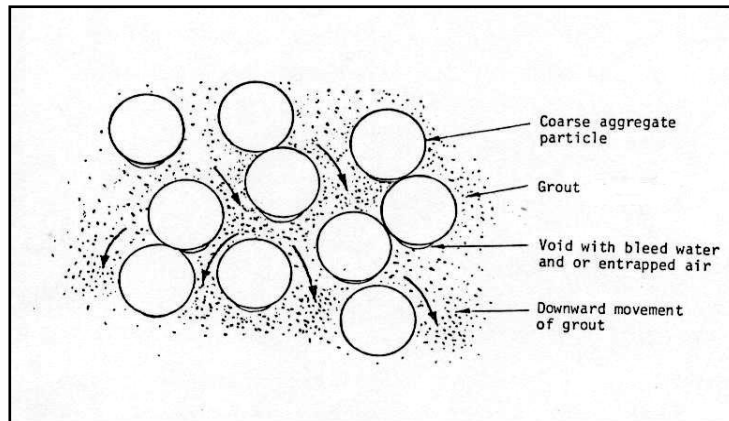


Figure 2: Typical settlement of grout underside of coarse aggregate particles.

3.2. Tensile strength

The tensile strength of prepacked concrete was also investigated at the age of 7, 28 and 90 days. The splitting tensile test data, obtained for both normal and prepacked concrete, are summarized in Table 3. The test results on tensile strength suggest that the tensile strength of prepacked concrete in all mixes was higher than in normal concrete. A similar trend has been observed by Abdelgader and Elgalhud (2008).

No causes were apparent for this relatively higher tensile strength development in prepacked concrete. However, the higher coarse aggregate content and the greater mechanical interlocking among the particles in prepacked concrete could be responsible for the development of higher tensile strength in it since, except for the amount of coarse aggregate and the method of placement, other factors like type and grading of aggregates, age, and method of testing were the same in normal concrete mix.

An important feature to note that there appears to be a good correlation between the compressive strength and tensile strength of prepacked concrete. As the compressive strength increased with time the tensile strength of prepacked concrete was also found to increase in the same manner.

Table 3: Compressive and tensile strength of concrete

Test Series	Admixture	Type of Concrete	Compressive Strength (MPa)			Tensile Strength (MPa)		
			7 days	28 days	90 days	7 days	28 days	90 days
Series - I	None	Prepacked	17.9	28.9	31.9	2.4	3.0	3.3
		Normal	23.5	32.8	33.2	2.1	2.9	3.4
Series - II	Superplasticiser	Prepacked	26.2	29.0	32.0	2.7	3.1	3.5
		Normal	29.5	35.3	44.8	2.2	2.7	3.2
Series - III	Expanding Admixture	Prepacked	35.8	42.3	45.6	2.8	3.3	3.7
		Normal	28.8	33.0	38.2	1.8	2.4	3.1

4. CONCLUSIONS

Prepacked concrete is made up of two phases - solid and liquid or grout phases. In this study two types of admixtures namely superplasticiser and expanding admixture were used in preparing the grout. Laboratory investigation on compressive and tensile strength revealed that at early ages prepacked concrete was somewhat weaker, but at later ages the strength of both normal and prepacked concrete were almost equal. Considering the admixture response to the strength development, the expanding admixture produced the best result. The expanding agent did not only provide expansion but also permitted a reduction in water-cement ratio in the grout.

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