## IV:(c) High Strength Impact Resistant Concrete

In certain situations such as roll on the roll off quays, the concrete is called upon to withstand severe impact and abrasion stresses arising from the off loading of heavy equipment and material. Concretes of compressive strengths 42 $N/mm^2$ subjected to such withering loads soon crack and fall apart. The class of concrete (strengths in excess of 55 $N/mm^2$ that meets these demands is under Middle East conditions, incumbent with the aforementioned problems. Even with well graded aggregates, high cement factors ($>$415 $kg/m^3$) and very low water:cement ratios ($<$ 0.36) are required to ensure consistent strength results. These measures, however, do not afford a workable concrete that is readily placed. The very high water reduction ($>$25%) and concurrent plasticity (50-75 mm slump) called for can only be supplied with an admixture which gives significant water reduction at high dosages without retardation. A melamine-formaldehyde based superplasticizer was used effectively in this type of application. A mix of 415 $kg/m^3$ cement contents, and 10 mm aggregate size, was used to pour 100 mm thick abrasion pads on the loading bays. The dense pads were proof tested and showed excellent capability of absorbing the shock impact stresses and also resistance to erosion by abrasive forces.

## IV:(d) Early Strength Development in Mixes Using ASTM Type V Cements

Precast concrete operations throughout the Middle East are often faced with the problem of coping with poor production cycles due to the use of Type V Cements. In these situations



many of the larger precast plants resorted to the use of superplasticizers to obtain reasonable if not desired manufacturing schedules. The lower $C_3A$ contents of Type V Cements which enhance the water reduction obtained with superplasticizers promotes early strength development and the requisite stripping strengths. Table IV shows the early strength capability of water reduced concrete containing a melamine-formaldehyde superplasticizer.

In some plants superplasticizers have been used to reduce the period of heat curing of concrete. The substantial mix water reduction which contributes to large increases in early strengths has been used by a Kuwait Precast Producer of building panels to reduce his 16 - 18 hour heat curing cycle to 6 hours thereby significantly improving his turnover of forms. Other beneficial effects included the ease of compaction, trowelability and a decrease in shrinkage cracks.

## IV:(e) Slump Loss

The high ambient temperature in the Middle East represents the most limiting condition in the use of superplasticizers. Many of these admixtures are susceptible to a rapid slump loss even at normal temperatures (22°C). At temperatures in excess of 22°C this trend is accellerated (Fig. II). Several techniques to overcome this problem have been suggested [3]. They are as follows:

(a) The production of an initial high slump, and allowing the natural slump loss to occur prior to discharge;

(b) Incremental addition of more admixture to restore the original slump;

(c) The use of a retarding superplasticizer;

(d) The addition of a hydroxycarboxylic (H.C.) type retarding admixture prior to the addition of a superplasticizer.

Method (a) is a counter-productive measure since it obviates the water reduction obtained through the use of a superplasticizer. The use of a retarding superplasticizer and repeated dosages are limited to specific uses or problem areas. Method (d) has flexibility in use and is a readily controllable means of reducing slump loss problems. Both Hester[4] and Mailvaganam[5] have reported the successful use of H.C. type retarders to offset the fall off of high workability. Two users of superplasticizers in the Kuwait area have incorporated the latter technique in their production cycle and effectively overcome previous slump loss problems.

Figs. (II) and (III) show the enhanced retention of the state of maximum workability obtained through the use of both H. C. type admixtures and retarding superplasticizers.

### IV:(f) Re-dosage of Superplasticizers to re-instate Workability

Due to the distances involved in the transport of concrete before it is placed, handling time is extended and substantial mixing time cannot be avoided. Prolonged mixing, particularly at elevated concrete temperatures, induces loss of consistency. Consequently there are not infrequent cases in which retempering of the mix with additional water to provide the desired workability is carried out. The serious loss of strength that results from the addition of water warrants



concern. It is, therefore, fruitful to consider the use of superplasticizers for this purpose. The addition of another dose of the admixture and a short remixing at the job site before discharge will provide a slump that is readily placed.

In the work done by Ravina[6] and Previte[7] it was shown that both conventional and superplasticizing admixtures could be used to minimize the amount of water required for retempering so that loss of strength was minimized. (Table V). More recent work by Seabrook and Malhotra[8] and Mailvaganam[5] indicates that superplasticizers can be used effectively to re-instate the initial consistency without loss of strength. (Table VI & Figs. IV & V). It is not certain as to how many subsequent additions can be made before it becomes detrimental to the concrete. Laboratory investigations by Perenchio[9] et al and field experience by Hester (4) indicate that depending on the type of superplasticizer used, incremental dosages of the admixture may result in either mild acceleration or significant retardation. The performance of each superplasticizing admixture in this respect is thought to be governed by an inherent response of the admixture to a given type of cement. Seabrook and Malhotra[8] found that the magnitude of the effect produced by redosage is closely related to the water:cement ratio. Mixes with water:cement ratios less than 0.55 appear to respond favourably to redosage and attain initial high slumps with adequate mix cohesion. At slumps of 0.65 there appeared to be a more drastic and cumulative effect whereby re-dosing at the same initial level produced severe bleeding and segregation. Most reports indicate that at least two repeated dosages are feasible. The effectiveness of a superplasticizer to increase slump appears to decrease as the age of the concrete increases (Fig. VI) and this effect should, therefore, be considered when establishing the maximum period during which re-dosage can be carried out.

Some precast users of superplasticizers in the Arabian Peninsula have used this technique to overcome loss of workability in the mixes. The more recent method of adding a conventional hydroxycarboxylic type retarder prior to the addition of a superplasticizer has found wide acceptance and therefore superseded the former technique in combating slump loss problems.

IV:(g) Watertight Concrete

The permeability of concrete is the principle property determining its resistance to attack by either aggressive ground water, salt solutions, sea water or dilute acids. Watertightness of a concrete depends primarily on the amount of cement and mixing water used and the length of the moist curing period. Concrete with water:cement ratio of less than 0.45 will be watertight if it has a low slump and is well placed and cured.

Despite the use of high cement contents the durability of the concrete cannot be taken for granted. Cracks resulting from shrinkage and thermal stresses, provide sites for entry of solutions containing chemical contaminants. The chief



solution to this ever present problem in the Middle East is, therefore the use of low water:cement ratios. In this respect water reducing admixtures can improve durability by reducing the water:cement ratio for a given workability (Fig. V). The use of conventional admixtures even at their highest possible dosage will not provide a water reduction in excess of 12-14%. Under Middle East conditions and the specification governing the quality of concrete, the water reduction achieved does not permit adequate cement reduction to offset the high drying shrinkage and thermal cracking that will occur. Superplasticizers on the other hand, depending on the dosage rate, afford up to 30% water reduction while maintaining stipulated strength values and minimizing crack formation. The good workability attained at low slumps provides a well compacted denser watertight concrete. Reduced porosity and cracking through the use of a superplasticizer coupled with proper curing thus increases the durability and serviceability of the concrete!

IV:(h) Harsh Mixes and Mixes Prone to Bleeding

The high water demand in concrete mixes results not only from high cement contents and ambient temperatures, but also due to the use of very fine sands (beach sands F.M. 1.6 - 1.9) and coarse aggregate with high dust content arising from the attrition of friable rims around the aggregate particles. Particle shape (highly angular) and improper gradations aggravate the problem. The Concrete Engineer, therefore, resorts to the use of harsher aggregate proportions in an attempt to improve overall mix workability and reduce water demand. Such mixes, however, are predominantly stoney, showing a serious lack of mortar content; concommittent problems are bleeding, segregation, poor compaction. The formation of ugly surface blemishes in the hardened concrete is, therefore, quite common. Superplasticizers due to their high water reducing and plasticizing capability permit the use of reasonable proportions of fine aggregate. Mortar rich mixes with increased cohesion at the desired workability are readily attained. The mix responds well to vibration enabling a good distribution of the aggregate throughout the mortar matrix, resulting in the reduction of settlement cracks and surface voids.

## Conclusion

Concreting in hot weather countries particularly in the Middle East presents manifold problems. However, two dominant mix parameters, namely water content of the mix, and consistency of the concrete, appear to govern most of the important properties pertinent to durability both in the fresh (workability bleeding) and hardened state (porosity, permeability, shrinkage etc.). A demanding water reduction (20% or more) with concurrent plasticity increase, is required to obtain desireable values of these properties and thus ensure the durability of the concrete. This requirement can only be supplied by a chemical admixture that not only provides an excellent dispersing action of the cement agglomerates, but also one which can be used at very high dosages without attendant adverse side effects. The active chemical constituents in the two most widely sold superplasticizers do not cause significant lowering of surface tension and therefore, enable their use at high dosage levels.



The dramatic mix modifications that are possible with the use of these admixtures, provides engineering objectives, which until recently were considered futuristic. Although, at the present time their use in the Middle East is confined to precast concrete and on site batching operations it is hoped that the Engineers operating in this area will in the near future examine the accumulated experience to permit their widespread use.