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hydroxycarboxylic type retarder prior to the addition of a superplasticizer has found wide acceptance and therefore superseded the former technique in combating slump loss problems.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.

REFERENCES

1. La Fraugh, R. W. "The Use of Superplasticizers in the Precast Industry"; International Symposium on Superplasticizers in Concrete, Ottawa, Canada May 1978.

2. Locher, F. W. "Schriftenreihe der Zementindustrie"; Vol. 40, 1973, pp 11-22 (German).

3. Hester, W. T. "High Range Water-Reducing Admixtures in Precast Concrete Operations"; Prestressed Concrete Institute Journal, July/August 1978.

4. Hester, W. T. "Field Applications of High Range Water Reducing Admixtures"; International Symposium on Superplasticizers in Concrete, Ottawa, Canada, May 1978.

5. Mailvaganam, N. P. "Slump Loss in Flowing Concrete"; International Symposium on Superplasticizers in Concrete, Ottawa, Canada, May 1978.

6. Ravina, D. "Retempering of prolonged mixed concrete with admixtures in hot weather; ACI Journal proceedings, LXXII No. 6, pp 291-295; June 1975.

7. Previte, R. W. "Concrete Slump Loss"; ACI Journal Proceedings, LXXIV, No. 8, pp 361-367; August 1977.

8. Seabrook, P. T. and Malhotra, V. M. "Accelerated strength testing of superplasticized concrete and the effect of repeated doses of Superplasticizers on Properties of Concrete"; International Symposium on Superplasticizers in Concrete, Ottawa, Canada, May 1978.

9. Perenchio, W. F., Whiting, D. A. and Kantro, D. L. "Water Reduction, Slump Loss and Entrained Air Void Systems as influenced by Superplasticizers"; International Symposium on Superplasticizers in Concrete, Ottawa, Canada, May 1978.

10. "Superplasticizing Admixtures in Concrete"; Joint Working Party Report 45-030. U.K.: Cement and Concrete Association and Cement Admixtures Association; January 1976.

11. "Hot Weather Concreting"; ACI Committee 305 Report of ACI Journal proceedings, Vol. LXXIV, No. 4; pp 319-320; August 1977.

12. Fookes, P. G. and Collis, L. "Problems in the Middle East"; Concrete, Vol. 9, No. 7, 1975.

13. Harrison, W. H. "Concrete and soluble salts in arid climates"; H.M.S.O. Overseas Building Notes, No. 139, 1971.

14. Browne, R. D. and Blundell, R. "Water Reducing Agents- Effect on long term properties of Concrete"; Symposium on Admixtures for Concrete, Cement and Concrete Association U.K., 1975.

15. Newman, A. J. "Problems of Concreting in arid climates"; H.M.S.O. Overseas Building Notes, No. 139, 1971.