4. the increased tendency for plastic shrinkage caused by rapid evaporation which occurs at high mix temperature and low relative humidity;
5. increased tendency for drying shrinkage and differential thermal cracking;
6. decreased durability due to the presence of deleterious salts in aggregates;
7. difficulty in maintaining desired air contents as a result of high mix temperatures;
8. The increased tendency for bleeding and settlement resulting from poor aggregate gradation.

III Concrete Specifications and the Contractor

Specifications usually stipulate the quality of concrete raw materials to be used and the fresh and hardened properties relevant to a particular class of concrete. They also specify the extent of control and supervision to ensure the serviceability of the concrete. Typical concrete parameters specified include: minimum cement contents, 7 and 28 day compressive strengths; maximum aggregate size; water:cement ratio and maximum slump.

The contractor, in attempting to provide a concrete meeting desired strength requirements, and stipulated durability criteria, is often compelled to accept the following impositions:

(a) Endure the costly and time-consuming placing due to the poor workability of mixes of low water:cement ratio.

(b) Use an uneconomical mix design due to the necessity of achieving high strength margins.

(c) Tolerate a high percentage of rejected units having severe blemishes and surface voids, due to the poor compaction of dry mixes;

(d) Perform such tests as necessary to demonstrate that his concrete meets the required absorption, drying shrinkage and moisture movement values.

For the contractor, therefore, strict adherence to specifications with conventional concreting practices brings a soaring cost to the project.

IV The Use of Admixtures

Recent studies have shown that traditional methods of increasing cement contents, to ensure strength and durability factors, account for some of the defects observed in both precast and in-situ concrete in the Middle East. The prudent use of admixtures often provides cost savings both in raw materials and labour, enabling the production of quality concrete with the limited equipment available.

Some of the commonly sought mix modifications (improvements) under such limited environmental and drastic geological conditions can be listed as follows:

(1) High water reduction and plasticizing effects for concretes where low water cement ratios and minimum cement contents are specified.

(2) Increased cohesiveness in harsh mixes and mixes prone to bleeding.

(3) Improved watertight character of the concrete, to prevent the ingress of water containing injurious concentrations of sulphate and chloride ions;

(4) An accelerated rate of strength gain in mixes using Type V (sulphate resisting) cements;

(5) A retarded rate of initial set and fall off of workability.

(6) A reduced rate of heat release, which occurs due to accelerated hydration;

(7) Reinstatement of the initially achieved workability.

IV:(a) High Range Water Reduction and Reduction of Cement Contents

The high water reduction required for mixes commonly used in the Middle East (viz. high cement contents and low water: cement ratios) entails the use of high dosages of conventional admixtures. Consequently, the reports of attendant adverse side effects (severe bleeding, retardation, heavy air entrainment) are quite common in many construction sites. In such situations, the use of superplasticizers, which provide the requisite plasticity and water reduction (20-25%) without damaging side effects, is a boon to the Concrete Engineer and Production Superintendent. Frequently specified water:cement ratios of less than 0.5 are readily met with superplasticizers at dosages of 2-2.5% (by weight of cement) for the 20% solids solution of melamine-formaldehyde type and 1.2 - 1.8% for the 40% solids solution of the naphthalene-formaldehyde type superplasticizers. The engineer is, therefore, assured of achieving favourable strength margins and hence reasonable economy in mix design. Table III shows the water reducing capability of a naphthalene-formaldehyde based superplasticizer

at two fixed workabilities.

The water reducing aspect of superplasticizers is seen in the construction of stabbits for a harbour breakwater project in Saudi Arabia. Sulphate resisting cement was specified for the 350 kg/m^3 cement content mix. The coarse aggregate (20 mm) was highly angular and of poor texture while the sand was a beach sand of F.M. 1.6. The maximum permitted water:cement ratio was 0.52 and the placing slump of 100 mm was expected to flow and fill the 4.2 m^3 mould with minimal vibration. The contractors desire to obtain favourable production cycles called for strength acceleration at early ages.

Several conventional lignosulphonate based water reducers were tried at high dosages. However, the high ambient temperatures (40^{o}C) and water demand by the fine sand made it impossible to attain the 0.52 water:cement ratio without severe bleeding and segregation, occuring in the mix.

The contractor in an attempt to offset the mounting costs of retaining hundreds of idle workmen agreed to try a superplasticizer - despite the high cost he would incur. A melamine formaldehyde based superplasticizer was used at a 2.5% dosage with the mix adjusted with a decreased fines content. A 20% water reduction (over plain mix) was achieved to provide a mix with the required water:cement ratio, plus adequate cohesion and workability at a 75 mm slump. Reasonable stripping strengths of 11 N/mm^2 were achieved, enabling the contractor to cope with the required production schedules.

The construction of large caissons for use in jetties involves the placing of large pours of concrete mixes with high cement contents (> 375 kg/m^3). The high core temperatures that build up are maintained for long periods due to the poor dissipation of heat to the hot surroundings. Consequently there is a great risk of thermal cracking occurring when the units are demoulded even after 72 hours. La Fraugh[1] has reported 11-20% cement reduction through use of superplasticizers in mixes of 415 kg/m^3 cement content while maintaining desired strength levels. The permissible cement reduction could well be used in these situations to reduce the core temperature and hence the potential cracking.

IV:(b) Sulphate attack and Alkali Aggregate Reaction

The complex variety of salts that exist in the Middle East pose problems of both internal and external attack on the concrete. External attack occurs by 2 principal means, typical sulphate attack by ingress of water containing chloride and sulphate ions, and salt weathering and salt crystalization. The latter is the result of salts crystallizing out in the pores of the concrete matrix and the aggregate particles, thereby setting up expansive forces. Intrinsic attack is due to typical alkali aggregate reaction.

Middle East Aggregates that are chemically reactive fall into two broad groups: one dominated by reactive silica minerals, and the other by carbonates. However, the amount of reactive ingredient necessary to cause damage is often so small that nearly all rock types may be considered suspect: all

the reactions involve alkali metal ions (Sodium & Potassium) together with other components of the aggregate and cement. Although the alkalies derive mainly from the cement, the salts contaminating the aggregates often make a major contribution to the total alkali present in the concrete.

The reason for expansion - cracking associated with alkali-aggregate reaction is not yet fully understood. However, on the basis of published literature[2] four main theories have been identified: (a) swelling of alkali-sensitive aggregate under the action of alkali-hydroxide solution, (b) volumetric increase associated with the transformation of the original particle to alkali-silicate hydrate, (c) swelling of the alkali-silicate gel when water has access to it and (d) development of osmotic pressure in the alkali-silicate solution.

The mechanisms outlined above, show the importance of the presence of intrinsic water and other related properties like porosity and permeability to concrete durability. It is, therefore, evident that the permissible water reductions (up to 30%) obtained through the use of superplasticizers play a significant role in reducing the extent of deterioration of concrete that results from the presence of intrinsic sulphate and chlorides or other reactive components in the aggregate. The lower water contents in mixes no doubt reduces the amount of chloride, sulphate and alkali hydroxide solutions present in the hardened concrete. Thus disruptive expansion through chemical attack is reduced.