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Remedy to Loss of Workability in Hot-Weather Concreting

Remède à la perte de la maniabilité lors du bétonnage par temps chauds

Gegenmittel zur Minderung der Verarbeitbarkeit von Betonieren bei heisser Witterung

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SUMMARY

This paper presents a study of the change in the degree of workability as influenced by variation of the initial temperature and water content of concrete mixes. Emphasis is placed on how to offset the loss of workability of a concrete mix cast in extremely hot weather. Apart from the limitation imposed by the material conditions relating to this work, the generality of certain findings is worth noticing.

RÉSUMÉ

Cet article traite de la mise en oeuvre influencée par la variation de la température initiale et de la teneur en eau des mélanges de béton. L'attention est portée sur les moyens de compenser la perte de maniabilité d'un mélange de béton coulé par temps extrêmement chauds. A part la limitation imposée par les conditions des matériaux en relation avec ce travail, le caractère général de certains résultats obtenus mérite d'être mentionné.

ZUSAMMENFASSUNG

Dieser Beitrag behandelt die Abhängigkeit des Verarbeitbarkeitsgrades von Betonmischungen von Anfangstemperatur und Wassergehalt. Es wird dargelegt wie die Verminderung der Verarbeitbarkeit infolge heisser Witterung vermieden werden kann. Die Allgemeingültigkeit der Zusammenhänge ist bemerkenswert.

1. INTRODUCTION

Freshly mixed concrete must be kept workable during the entire placing period to permit satisfactory compaction and finishing. Also, it must be kept plastic for a sufficient period so that succeeding lifts can be placed without development of cold joints.

Hot-weather concreting could result in loss of workability or increased water demand, premature setting, formation of plastic shrinkage cracks and loss of strength [2,5,7]. The increased water demand and placing problems can lead to highly permeable concrete which is undurable. To counteract the loss of workability and rapid setting encountered in hot weather conditions, it is imperative to use a suitable set-retarding and water-reducing admixture in the concrete mixture [1,6,8].

Based on wide experimental data, this paper investigates the way by which workability is affected and could be treated at high environmental temperatures. The British compacting factor test was chosen in the present work to measure the degree of workability. The test bears close relation to the definition of workability; it is more sensitive than the slump test for stiff concrete mixes, and is more suitable for field use than the remoulding and Vebe tests.

2. TESTING PROGRAMME, MATERIALS AND PROCEDURES

Concrete mixes were generally designated either with admixture or without admixture. Mixes containing the admixture were classified according to the dosage level into three classes: normal, above normal and high. The normal dosage amounts for 0.2 ℓ per 50 kg of cement; the other two levels are 0.25 and 0.3 ℓ, respectively. For simplicity, these dosages will be denoted as 0.4%, 0.5% and 0.6%, respectively.

Mixes being so classified were prepared and tested at three different ranges of ambient temperatures, viz: from 22 to 24°C (at laboratory conditions), from 30 to 33°C, and from 40 to 44°C (outdoors). The corresponding initial temperature of the fresh concrete itself ranged from 24 to 25°C, 28 to 29°C, and from 33 to 34.5°C, respectively.

As regards the water content, the concrete mixes fell into three categories: 190, 300 and 210 kg per m^3 of concrete. The water-cement ratios ranged from 0.4 to 0.65, and were varied in 0.05 increments. Well-proportioned crushed coarse ggregate with a maximkum size of 19 mm, and ordinary Portland cement were used in all the mixes. The fine aggregate had a fineness modulus of 2.4.

The admixture used was the FEBFLOW Retarding Concrete Plasticiser, manufactured by FEB (Great-Britain) Ltd [4]. The admixture, a non air-entraining, water-reducing, set-retarding admixture, is a concentrated aqueous solution of lignosulphonic base, and free from added chlorides and nitrates. It complies with Type D of ASTM C 494 [3].

Non-laboratory concrete mixes were mixed and tested under an open-air shelter. No special precaution was taken to control the evaporation of the mix water during testing. The intention was to have conditions similar to those prevailing at the job sites.

3. PRESENTATION AND INTERPRETATION OF TEST RESULTS

The results of the compacting factor test for the concrete mixes (with and without the retarding/reducing admixture) having different water contents, different water-cement ratios and different initial temperatures are given in Table 1.

Water content, kg/m³ of concrete	Water-cement ratio	Without admixture						With a set-retarding, water-reducing admixture added in (by wt. of cement)																	
								0·4%		0·5%		0·6%		0·4%		0·5%		0·6%		0·4%		0·5%		0·6%	
		C.F.	I.T. °C	C.F.	I.T. °C	C.F.	I.T. °C	C.F.	I.T. °C	C.F.	I.T. °C	C.F.	I.T. °C	C.F.	I.T. °C	C.F.	I.T. °C	C.F.	I.T. °C	C.F.	I.T. °C	C.F.	I.T. °C	C.F.	I.T. °C
190	0·40	0·892	24·5	0·875	29	0·867	33·5	0·924	24·5	0·941	24	0·945	24	0·914	28	0·924	28	0·925	28·5	0·898	34	0·915	34	0·920	33
	0.50	0·895	24·5	0·880	28	0·859	34	0·925	24·5	0·938	24	0·938	24·5	0·909	28	0·929	28	0·931	29	0·905	34	0·912	34	0·922	33
	0.60	0·887	25	0·883	29	0·865	34	0·929	24	0·932	24	0·940	25	0·926	28·5	0·919	28	0·928	29	0·895	33·5	0·920	34	0·914	34
	0.65	0·893	24·5																						
200	0.40	0·920	24	0·910	28·5	0·900	33	0·940	25	—	--	0·951	24							0·923	34			0·932	34
	0.50	0·924	24	0·916	28·5	0·895	33	0·941	25	0·953	24	0·958	24	0·934	28·5	0·941	28·5	0·943	29	0·925	34	0·927	34	0·936	33·5
	0.60	0·918	25	0·908	29	0·891	33·5	0·946	24·5	—	-	0·947	24·5		--					0·920	34	—	—	0·930	34
	0·65	0·926	24																						
210	0·40	0·941	24	0·926	28·5	0·892	33·5	0·953	25	0·962	24	0·97	24·5	0·944	28	0·953	28	0·957	28·5	0·912	33	0·937	33·5	0·955	34
	0·45	0·950	24	0·929	28·5	0·910	33	0·952	25	0·967	24	0·968	25	0·950	28	0·948	28	0·962	28·5	0·917	33	0·933	33	0·948	34·5
	0·50	0·943	24	0·931	28	0·893	34	0·948	25	0·964	24	0·963	25	0·945	28	0·950	29	0·955	28·5	0·914	33	0·930	33	0·951	34·5
	0·55	0·938	24·5	0·925	28	0·913	33	0·957	25	0·958	24	0·975	24·5	0·940	29	0·954	28·5	0·960	28	0·923	34	0·932	33	0·952	34
	0·60	0·942	24	0·932	28	0·900	33·5	0·960	24·5	0·970	24	0·971	25	0·937	28·5	0·952	29	0·961	28	0·928	34	0·930	33·5	0·946	34·5
	0·65	0·945	24	0·925	28·5	0·910	33	0·952	24·5	0·955	25	0·967	24	0·942	28·5	0·945	28.5	0·952	28	0·925	33·5	0·927	33·5	0·945	34·5

Table 1 Compacting factor (C.F.) of concrete, with and without set-retarding, water-reducing admixture, at different initial concrete temperatures (I.T.) and for various water contents and water-cement ratios

On reviewing these results, the following observations can be made:

- The effects of the initial concrete temperature and the water content are particularly significant. The compactin factor decreases considerably as the initial concrete temperature increases; the same tendency is detected when the water content is decreased.
- For a given water content and at a specific initial temperature the compacting factor increases with the addition of the retarding/reducing admixture. This increase is greater at higher admixture dosages.
- The effect of the water-cement ratio appears to be insignificant when the values of the water content, the initial temperature and the admixture dosage are kept unchanged.

Based on the last observation, the average value for the compacting factor was considered the representative value at a certain initial temperature, water conent and admixture dosage. Making use of these results, the relationship between the compacting factor and initial concrete temperature is shown in Fig. 1 for different values of water content and dosage level. The figure explicitly shows that the respective relationship is linear, and that the straight lines are almost parallel to each other. It is also apparent that the said linearity is maintained fairly well for a range of initial temperatures extending between 20°C and 37.5°C. This range, fortunately, covers in practice the overwhelming majority of concrete temperatures encountered in the tropical and subtropical countries throughout the whole year. Referring to Fig. 1, the linear relationship may be mathematically expressed as:

$$CF = -mT + k \qquad (1)$$

where CF is the compacting factor; T is the initial concrete temperature in degrees Celsius; m is the slope of the line, and k is the intercept.

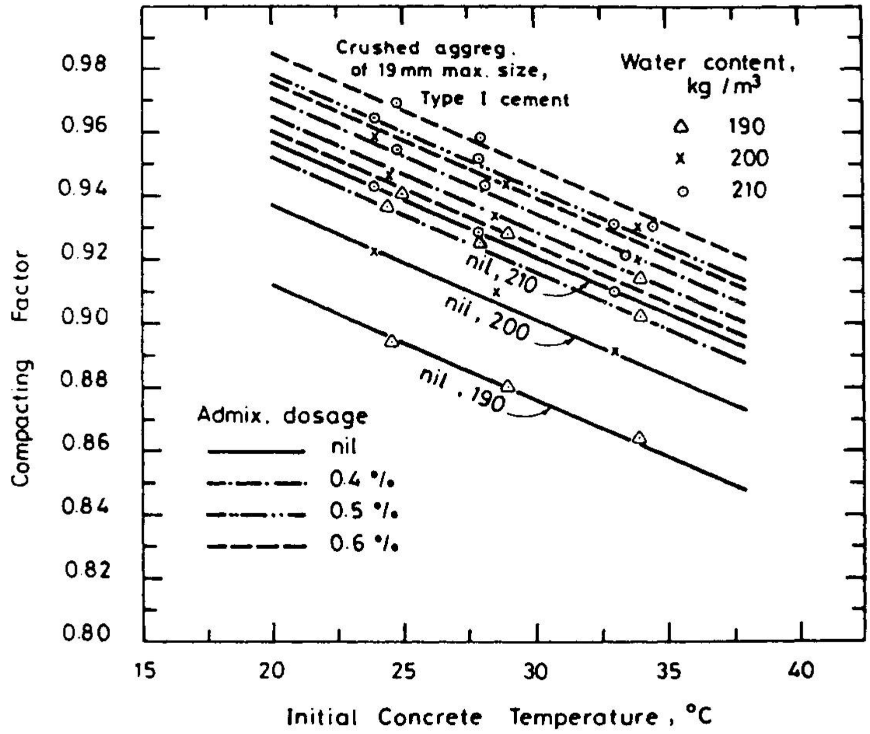

Fig. 1 Compacting factor as influenced by initial concrete temperature, water content and dosage of retarding/reducing admixture

The coefficient k is dependant on the water content and dosage level. Since all the lines are parallel, the slope m is independent of the values of water content and admixture dosage. The value of m represents, in fact, the value of the rate of drop in the compacting factor (or loss of workability) due to a unit rise in the initial concrete temperature. The latter tends to be higher in hot weather.

The value of m has been found equal to 0.0037, and hence Eq. 1 becomes:

$$CF = k - 0.0037T \qquad (2)$$

Making use of Fig. 1 and/or Table 1, the values of the coefficient k were calculated and are listed in Table 2.

Water content, kg/m^3	Coefficient k			
	Zero dosage	0.4% dosage	0.5% dosage	0.6% dosage
190	0.985	1.026	1.03	1.034
200	1.01	1.038	1.045	1.048
210	1.03	1.044	1.051	1.058

Table 2 Values of coefficient k at different water contents and dosage levels

By virtue of the data of Table 2, Fig. 2 was plotted. The figure illustrates the relation between the coefficient k and the water content at dosage levels 0, 0.4% and 0.6%; the relationship tends to be linear for all the dosage levels. However, not all the family of lines are parallel. Evidently, the figure permits a reliable linear extrapolation for water contents down to 180 kg/m^3 and up to a 220 kg/m^3. Between the above two limits every value of the water content used in practice lies.

Figure 2 reveals distinctly that the lower the water content in a concrete mix, the more influential the role of the admixture dosage in improving the

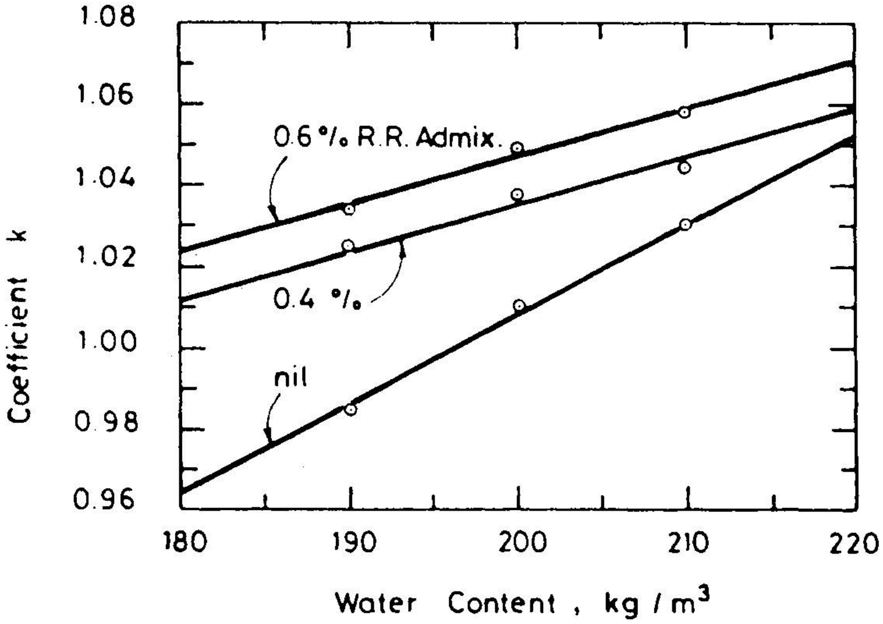

Fig. 2 Coefficient k versus water content at various dosage levels

workability of the mix. Further examination of Fig. 2 indicates that for a specific admixture dosage, the rate of increase in the value of the coefficient k is almost constant over the whole range of practical water-contents.

These observations suggest that when the water content is low, the optimal dosage of admixture intended to offset the loss of workability at hot-weather temperatures could be taken about 0.4%, whereas a dosage of 0.6% would be optimum at high levels of water content. Intermediate dosages would best suit moderate water contents. Use of admixture dosages greater than 0.6% is not a recommended practice, because the likely relative gain in the compacting factor value is very limited and accordingly is not justified by the increase involved in cost. To this end, the importance of Eq. 2 and Fig. 2 becomes evident. Their utilization is advantageous in the following cases:

- Prediction of the compacting factor, if the values of the initial concrete temperature, the water content and the dosage level are known.
- Determination of the water content, when the initial temperature is known and the compacting factor and dosage level are decided upon.
- Selection of the dosage level in case the values of initial temperature, compacting factor and water content are given.

The latter case is of great help when designing concrete mixes in hot weather while applying standard methods of mix design. It should be remembered, however, that utilization of Eq. 2 and Fig. 2 remains within the limits of the materials used.

4. CONCLUSIONS

Based on this study and within the limits of the materials used and the conditions covered, the following conclusions can be drawn:

- The initial concrete temperature and not the ambient temperature has a pronounced effect on the workability of concrete mixes; the workability degree significantly falls with the increase of this temperature. Nevertheless, the initial concrete temperature rises in hot weather.
- A loss in the compacting factor of about 0.0037 per 1°C rise of initial temperature was found.
- In Kuwait and similar hot regions, concrete cast in summer can be expected to have a lower compacting factor of about 0.05 than a similar mix cast in winter.
- Addition of water-reducing and retarding admixture can favourably offset the loss in workability of concrete cast at high temperatures. The lower the mixing water content, the more effective the role of an admixture dosage in improving the workability.

  Dosage of FEBFLOW Retarding Concrete Plasticiser would be optimally recommended at about:

  0.4% for mixes of originally low workability,
  0.5% for mixes of originally medium workabilty,
  and 0.6% for mixes of originally high workability.
- For a given water content, the water-cement ratio seems to have no significant effect on the compacting factor of well-designed concretes with or without water-reducing and retarding admixtures and irrespective of the concrete temperature.

5. REFERENCES

1. ACI Committee 212, Admixtures for Concrete. Concrete International: Design & Construction, May 1981.
2. ACI Committee 305, Recommended Practice for Hot Weather Concreting. ACI Journal, July 1971.
3. ASTM Standards, Concrete and Mineral Aggregates (C494), ASTM Vol. 04.02, 1984.
4. A Guide to FEB Products. FEB (Great Britain) Ltd., 1977.
5. NEVILLE A.M., Properties of Concrete. Pitman Publishing, 1977.
6. ORCHARD D.F., Concrete Technology, Vol. 1: Properties of Materials. Applied Science Publishers, 1979.
7. POPOVICS S., Concrete-Making Materials. McGraw-Hill, 1977.
8. ROPKE J.C., Concrete Problems - Causes and Cures, McGraw-Hill, 1982.