RETEMPERING OF READY-MIXED CONCRETE IN RIYADH, SAUDI ARABIA

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ABSTRACT

Retempering is typically done to restore concrete slump back to specified limits. The practice is known to result in some loss of strength which is proportional to the amount of water added. When retempering of concrete is done only to restore slump as per ACI 116 definition, it causes a loss in compressive strength of 7 to 10 percent, but it can be much higher depending on the amount of retempering water added. The practice of retempering in Saudi Arabia is expected to be far worst as the addition of water at the jobsite is frequently done to increase slump beyond the specification's limits.

The effect of retempering on the strength of ready-mixed concrete (RMC) in Riyadh was investigated. This investigation covers 12 construction sites and represents 11 ready-mixed concrete (RMC) plants operating in Riyadh. The addition of water was found to correlate well with the increase in slump. Also, the reduction in strength was found to be proportional to the increase in slump. In cases where controlled amount of water is added to restore the slump within the specification's limits (100 ± 25 mm), the reduction of strength was below 10%. However, when the amount of water added is not controlled, reduction of strength may be as high as 35%. Based on these findings, it is strongly recommended that the practice of adding water to RMC at the job site to restore or increase slump should be prohibited. Superplasticizer can be used instead of water to adjust slump. This recommendation has been adopted by the Municipality of Riyadh and communicated to all RMC factories operating in Riyadh to abide by it.

Keywords: *concrete, compressive strength, ready-mix, retempering, Saudi Arabia, Quality*

الملخص

إعادة تشغيل الخرسانة عادة تكون من اجل استرجاع مقدار هبوط إلى الحدود المطلوبة . ومن المعروف أن هذه الممارسة تؤدي إلى فقد بعض مقاومة الضغط ويتناسب ذلك مع كمية الماء المضاف .عندما تكون "إعادة تشغيل الخرسانة " من اجل استرجاع مقدار الهبوط حسب تعريف المعهد الأمريكي للخرسانة فإن ذلك يؤدي إلى فقد مقاومة الضغط بنسبة ٧ إلى ١٠% . ولكن يمكن أن تكون هذه النسبة أعلى بكثير وذلك حسب كمية الماء المضافة لإعادة التشغيل .و يتوقع أن تكون ممارسة "إعادة التشغيل" في المملكة أسوأ بكثير لأنه عادة ما يضاف الماء في الموقع لزيادة مقدار الهبوط أكثر من حدود المواصفات.

في هذه الورقة تمت دراسة تأثير "إعادة التشغيل "على مقاومة الضغط للخرسانة الجاهزة في مدينة الرياض. و تغطي هذه الدراسة ١٢ موقعاً إنشائياً وتمثل ١١ مصنعا للخرسانة الجاهزة في مدينة الرياض. أوضحت نتائج الدراسة أن إضافة الماء في الموقع

ترتبـط بشـكل قوي بزيادة مقدار الهبوط ، ففي حالة التحكم في إضافة الماء ليكون مقدار الهبوط ضمن حدود المواصفات (١٠٠± ٢٥ مم) فان ذلك ينتج عنه فقد في مقاومة الضغط أقل من ١٠%. ولكن عندما لا يوجد تحكم في كمية الماء المضافة فقد يصل الفاقد في مقاومة الضغط إلى حوالي ٣٥%. بناءاً على هذه الاستنتاجات يوصى بقوة أن يمنع ممارسة إضافة الماء إلى الخرسانة الجاهزة في الموقع لإعادة أو زيادة مقدار الهبوط (قابلية الخلطة التشغيل) و يستعاض عن ذلك باستخدام الملدنات الكيميائية عند الضرورة. و يتم العمل بهذه التوصية الآن في برنامج مراقبة جودة الإنتاج في مصانع الخرسانة الجاهزة و الذي تقوم به أمانة مدينة الرياض.

1. INTRODUCTION

Retempering is defined by ACI 116 [ACI, 1990] as the "Addition of water and remixing of concrete or mortar which has lost enough workability to become unplaceable or unsaleable". Retempering inevitably results in some loss of strength compared with the original concrete. Laboratory research as well as field experience show that strength reduction and other detrimental effects are proportional to the amount of retempering water added [Cook, 1943; Meininger, 1969; Beaufait, and Hoadle, 1973; Cheong and Lee, 1993]. When retempering of concrete is done only to restore slump as per ACI 116 definition, it causes a loss in compressive strength of 7 to 10 percent, but it can be much higher depending on the amount of retempering water added as can be seen from Figure 1. Some empirical relationships have been suggested to quantify the effect of retempering on strength [Burg, 1983] but, in practice, the precise amount of retempering water may not be known, if only because partial discharge of concrete from the mixer had occurred prior to the realization of the slump loss [Neville, 1995]. Since retempering increases the original water/cement ratio of the mix, it is arguable that it should not be permitted where the original water/cement ratio was directly or indirectly specified.

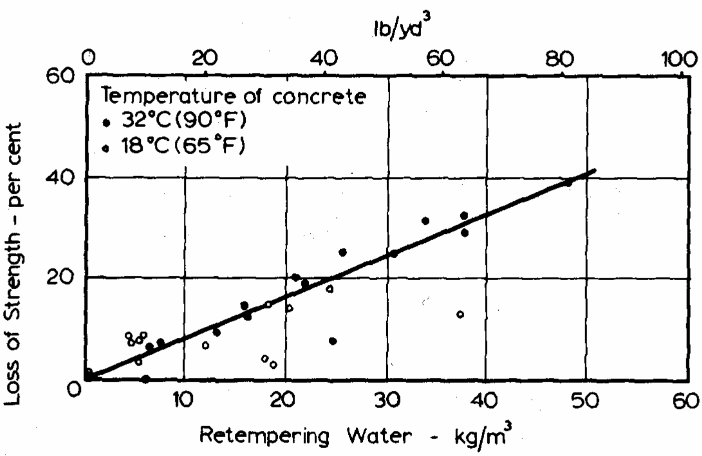

Figure 1: Effect of retempering on the compressive strength of concrete. (Neville, 1995)

Top

In Riyadh, the addition of water at the jobsites is done to increase workability as demanded by contractors and therefore is different than the classical definition of retempering. The need to add water to ready-mixed concrete (RMC) is particularly more serious during the summer as hot weather conditions have strong impact on workability and accelerate the loss of slump with time [ACI 305, 1991; Scanlon, 1993]. The effect of the local practice of retempering on the quality of RMC in Riyadh has not been quantified before. Quantifying the effect of such practice on the properties of RMC is very important in relation to the quality scheme for RMC started by the Municipality of Riyadh in 1415H [Al-Negheimish et al., 1999; Municipality, 2000]. As part of this scheme, random checking of the quality of concrete is done at the plant. The results from the Municipality program show that concrete with acceptable quality is produced by most RMC plants [Alhozaimy et al., 1999, Alhozaimy and Al-Negheimish, 1999]. Extensive studies have shown that the strength of RMC at the job site is identical to that measured at the RMC plant provided that water is not added to the delivery trucks after leaving the plant [Al-Negheimish and Alhozaimy, 2001]. Therefore, retempering of concrete at the construction site is still one of the major risks to concrete quality which needs to be addressed urgently.

The objective of this study is to examine the adverse effect of adding water to the RMC at site during the hot summer months and its impact on the compressive strength. For this purpose, an investigation covering 12 construction sites and representing concrete from 11 RMC producers operating in Riyadh was conducted. Physical properties of fresh concrete (slump and temperature), along with the 28-day compressive strength of hardened concrete, are measured for samples taken from the delivery truck immediately upon arrival to the construction site and later during the discharging operation. The addition of water, if any, is documented.

2. EXPERIMENTAL PROGRAM AND PROCEDURE

This investigation covers 12 construction sites and represents 11 RMC plants operating in Riyadh. The investigation was conducted during the hot summer months of August and September. The procedure involves sampling of concrete from delivery trucks both at the plant and after delivery to construction sites. For this purpose, the project team visited these plants without prior arrangement and selected randomly a truck already loaded with concrete. The truck was requested for concrete sample at the plant. The first wheel barrow was discarded. Concrete from the second wheelbarrow was used to perform slump test and mould strength specimens. Slump and concrete temperature were measured following ASTM procedures [ASTM, 1992]. In addition, ambient conditions were recorded. The cubes were molded using rigid plastic mold and sealed using plastic cover. The cubes were stored in the plant's laboratory for the initial 24 hrs before transferring them to the Concrete Laboratory King, Saud University (KSU) for curing and testing.

Top

The project team followed the truck to the site. Upon arrival to the construction site, two concrete samples were procured from the same delivery truck. The first sample was collected from the truck immediately upon arrival to the construction site and before any water is added to the truck. The second sample was procured after discharging of approximately half of the truckload. Any addition of water to the delivery truck before taking the second sample was documented and the amount estimated. For each sample, ambient conditions, concrete temperature and slump were measured and 6 cubes were made for the determination of compressive strength at 7 and 28 days. All cubes were molded using rigid plastic mold and sealed using plastic cover and stored under shade at the construction site for the first day, then they were transported to KSU Laboratory for curing and testing.

All cubes were cured in lime-saturated water until testing at the age of 7 and 28 days. Molding and testing of the cubes was done in accordance with BS 1881 Part 108 and Part 116, respectively [BSI, 1981].

3. RESULTS AND DISCUSSION

The results of slump, concrete temperature, and compressive strength of concrete collected from the RMC truck upon arriving to the construction site and before any water was added are given in Table 1. The table also includes the same properties measured after discharging of approximate half of the truckload. Furthermore, any addition of water to the truck during discharging was noted. The strength reported in the table is the average compressive strength based on 3 cubes tested at the age of 28 days.

The results given in Table 1 were obtained from twelve concrete delivery trucks selected randomly for sampling concrete for this study. These trucks represent eleven different RMC plants operating in Riyadh. Out of these twelve samples, water was added, in different amounts, to concrete in seven of the trucks during discharging operation at the site to restore the lost workability. In some cases, water was added to increase the slump (above the specification's limits) upon the request of the contractor to speed up casting operations and to reduce efforts needed for compaction.

It is to be mentioned here that in all of the cases studied, no water was added to concrete in the delivery truck after leaving the plant and upon its arrival at site. In each case, the truck was followed and monitored by the project team during the whole trip from the plant to the construction site. That is to say that concrete sampled from the truck upon its arrival at site serve as a reference and has been taken as such for comparing properties of concrete before and after addition of water at the site.

The data summarized in Table 1 were studied and analyzed to examine the changes in properties of RMC (slump, compressive strength) during discharging operation and the effect of the addition of water (if any) on these properties. Figure 2 shows the effect of addition of water to concrete at site during discharge operation on the compressive strength. It can be

Top

seen from the figure that there is a considerable decrease in strength in cases where water was added to concrete to increase workability. The increase in slump as a result of adding water to concrete at site is shown in Figure 3. From this figure it is clear that slump from middle of the truckload will most likely decrease when compared with the slump upon arrival as shown by the five cases where no water was added (Samples No.8 through No .12 in Table 1). In comparison, when water is added the slump will increase, sometimes substantially depending on the amount of water added during discharge, as shown by the other seven cases (Samples No.1 through No.7 in Table 1). In cases where limited amount of water is added to compensate for loss of slump (Sample No. 1 and 2 in Table 1), the decrease in strength is below 10 percent. However, the decrease in strength is in the range of 25-35% when the amount of water added is not controlled as indicated by the high slump at middle of the load (Sample No. 3-through No.7, Table 1). Figure 4 shows strong correlation between the changes in strength and change in slump for the 12 cases. The increase in slump (due to the addition of water) will result in proportional decrease in strength. The rate of reduction in compressive strength is approximately 2% for each 10 mm increase in slump. The reduction in strength could be as high as 35%.

4. CONCLUSIONS

The addition of water to RMC truck at the construction site may result in substantial reduction in strength. The reduction in strength was found to be proportional to the increase in slump. Large increase in slump means higher reduction in strength. When the amount of water added is not controlled, reduction of strength may be as high as 35%. In cases where controlled amount of water is added to restore the slump within the specification's limits (100 ±25 mm), the reduction of strength may be below 10%. Based on this study it is strongly recommended that adding water to RMC at the construction site to compensate for loss of workability should be prohibited. In cases where slump of concrete is below the specified limits upon arrival at the job site, slump can be adjusted by the use of chemical admixtures. In particular, high range water reducing admixtures (superplasticizers) is known to be an effective way to restore workability without adversely affecting other properties. This recommendation has been adopted by the Municipality of Riyadh and communicated to all RMC factories operating in Riyadh to abide by it.

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Top

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Table 1: Summary of data and results from retempering at construction sites.

Sample No.	Ambient conditions*		Site (upon arrival)			Site (middle of load)			Water added	Change in slump (mm)	Change in strength (%)
	Air Temp., ºC	Relative humidity (%)	Concrete Temp., ºC	Slump (mm)	28-day Strength (MPa)	Concrete Temp., ºC	Slump (mm)	28-day Strength (MPa)			
1	35	10-15	32	75	39.6	32	93	35.9	Yes	+18	-9.3
2	45	10-15	34	80	33.2	37	110	30.4	Yes	+30	-8.43
3	47	10-15	39	75	41.6	39	220	31.2	Yes	+145	-25.0
4	46	10-15	39	95	43.1	35	230	28.3	Yes	+135	-34.3
5	44	10-15	34	70	28.4	34.5	220	20.7	Yes	+150	-27.1
6	44	10-15	35.5	145	40.3	35.5	220	30.2	Yes	+75	-25.1
7	36	10-15	33.9	100	41.0	34.0	180	32.7	Yes	+80	-28.6
8	44	10-15	31.0	70	46.6	32.3	60	48.0	No	-10	+3.0
9	47	10-15	33.0	160	33.7	34.0	155	36.1	No	-5	+7.1
10	44	10-15	36.5	120	44.0	35.5	125	43.8	No	+5	-0.5
11	46	10-15	36.0	210	42.7	36.0	190	43.8	No	-20	+2.6
12	48	10-15	33.5	220	30.4	33.0	190	28.9	No	-30	-4.9

* Ambient conditions as measured at the construction site

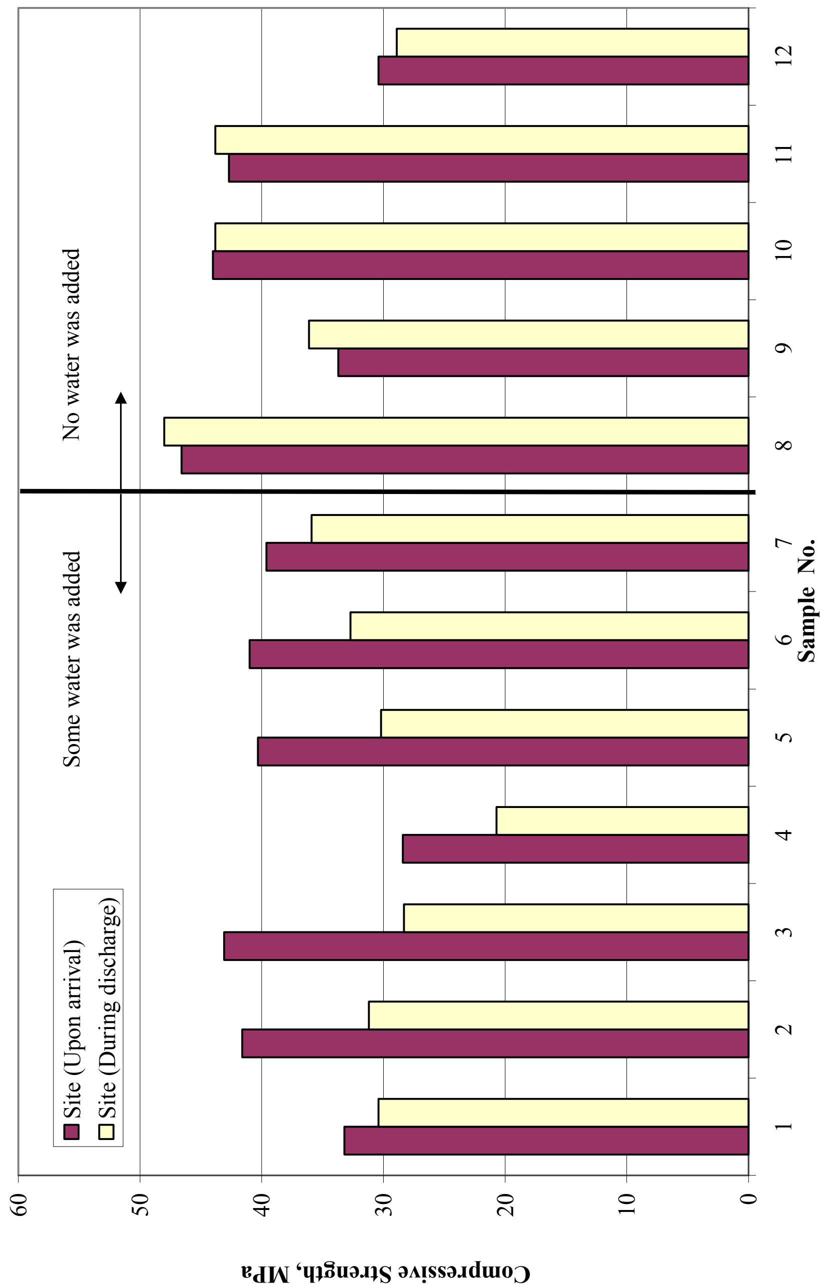

Figure 2: Effect of retempering on the compressive strength of ready-mixed concrete

Top

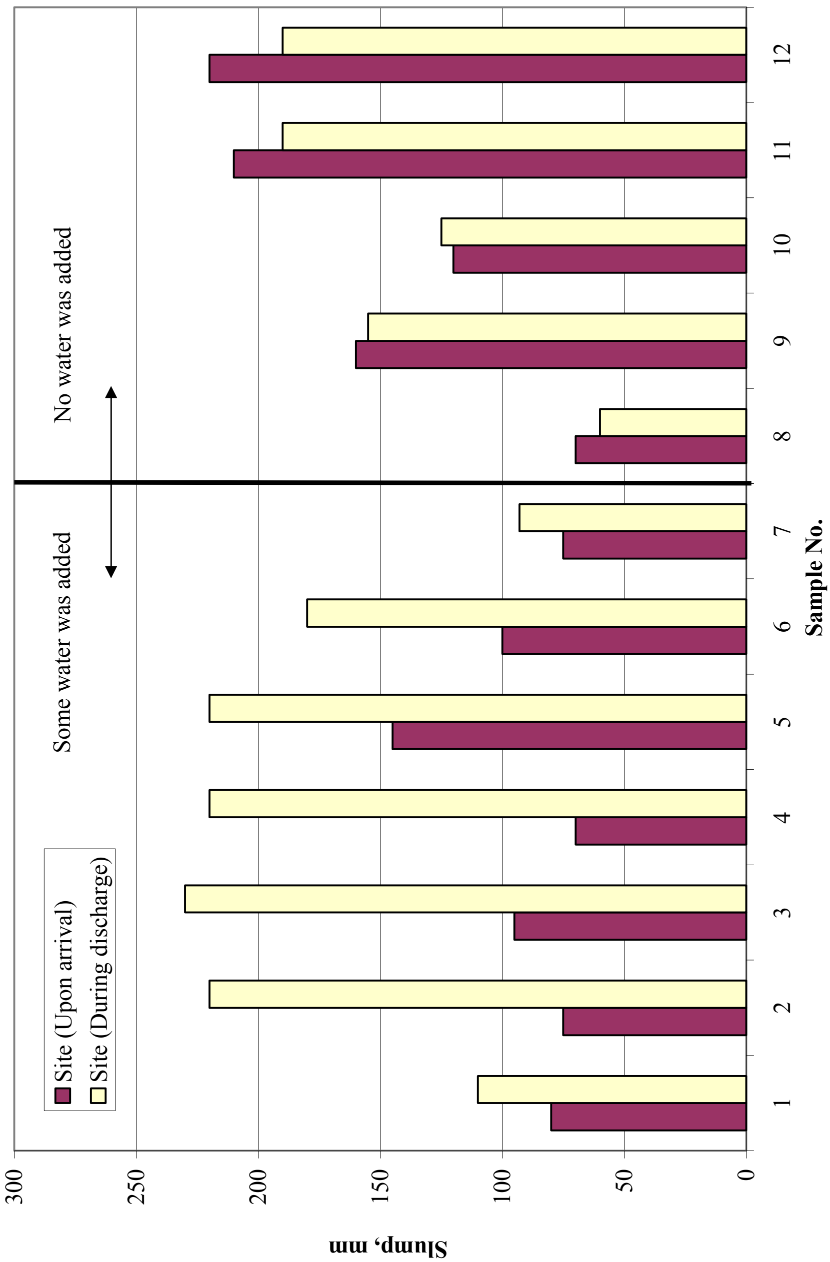

Figure 3: Effect of retempering on the slump of ready-mixed concrete

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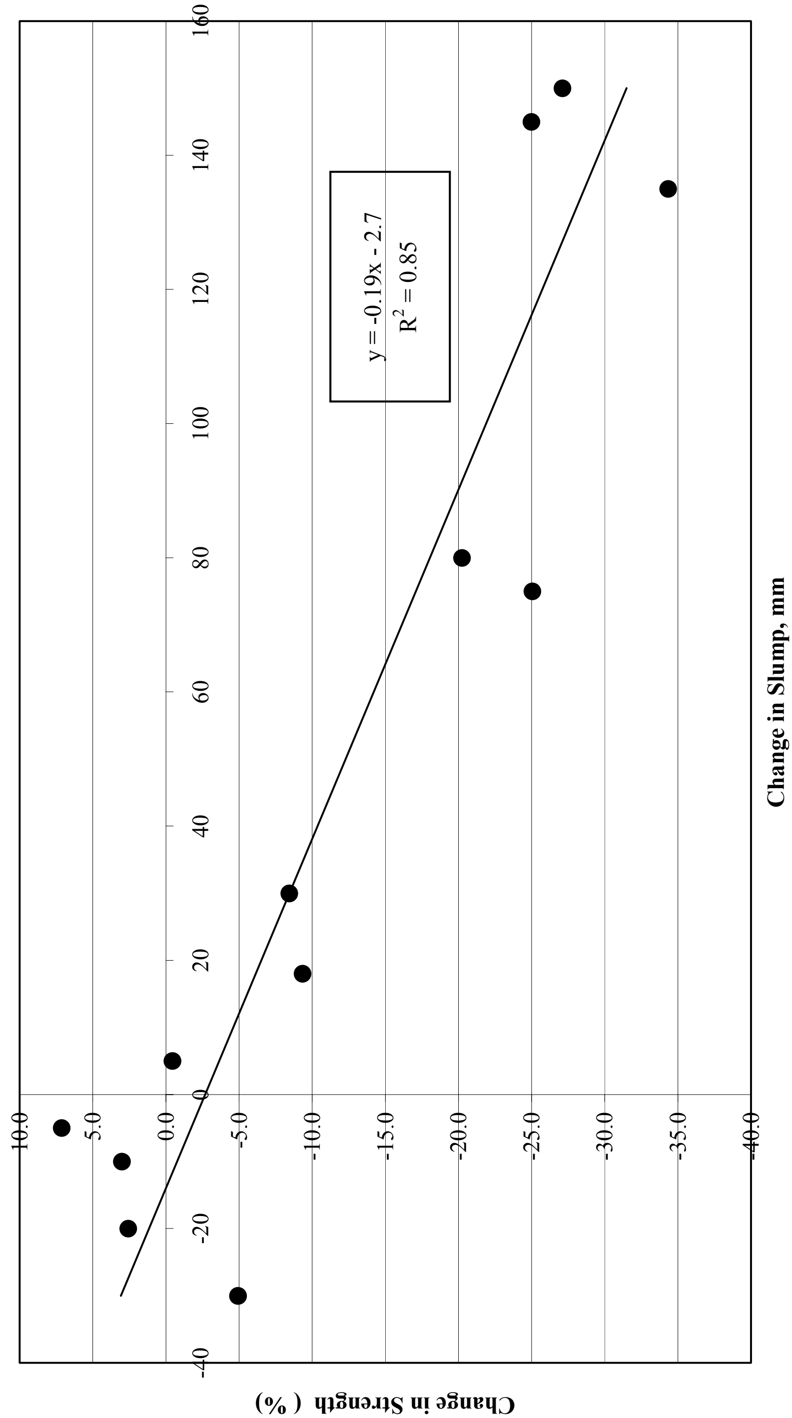

Figure 4: Changes in strength vs. changes in slump as a result of retempering of ready mixed concrete.

Top