RETEMPERING OF CONCRETE

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ABSTRACT:
Retempering is the process of changing the consistency of a concrete mixture by adding water and remixing. As it is common to send the concrete to the placement site with slightly less water than the maximum that may be used, it is expected that a specified amount of water can be added if necessary. The contractor may add the water because the mixture arrives at the site in a condition that would make placement and finishing difficult. These difficult HCCs are often called harsh mixtures. The usual cause of a harsh mixture is sand with a high void content. Sands with a high void content are usually irregular in shape with an abundance of re-entrant angles and internal fractures and voids. Iron-stained clay coatings are common. Other causes of concrete that seems too dry are improper grading of the aggregate and the presence of mud or mud coatings on the aggregate Mixtures with a low w/c (below 0.45) can be difficult to place unless an effective water reducer is used. A good air-void system or the presence of fly ash as a substitute for part of the cement can help make a mixture with a low w/cm more workable

According to ACI 116 [ACI, 1990] Retempering is defined by 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. Water additions in excess of the proportioned maximum water content or w/cm to compensate for loss of workability should be prohibited. Adding chemical admixtures may be very effective to maintain workability. Strength reduction and other detrimental effects are proportional to the amount of retempering water added.

Figure: appendix fig1

Fig 1: Retempering of concrete

***Water needed for retempering of concrete*:**

Fig. 4 from appendix illustrates the water needed for retempering of concrete mixture in relation with mixing time. As seen from the graph, the relation between the amount of water used for retempering and the mixing time is of a parabolic shape with a statistically significant coefficient of correlation of 0.999. The relation is rather steep up to 120 min of mixing, and then the increase is slight later on. Based on the relationship, for instance, for a mixing period of 120 min, an amount of about 36 kg/m3 water is needed for retempering to restore the initial slump. Such a significant amount of water addition to the concrete mixture resulted in an appreciable increase in the water to cement ratio, and this reflected in a substantial strength loss, accordingly. The amount of water needed for retempering will obviously be varied depending on the specific properties of cement used and the ingredients of concrete. For instance, the amount of water added to the mixture will decrease as the initial slump increases. In practical terms, the strength of concrete decreases as the additional water increases and that is why a strength loss of over 40% corresponding to a mixing time of 150 min is observed for concrete retempered with water as seen from Fig. 2 from appendix.

Figure: appendix fig2

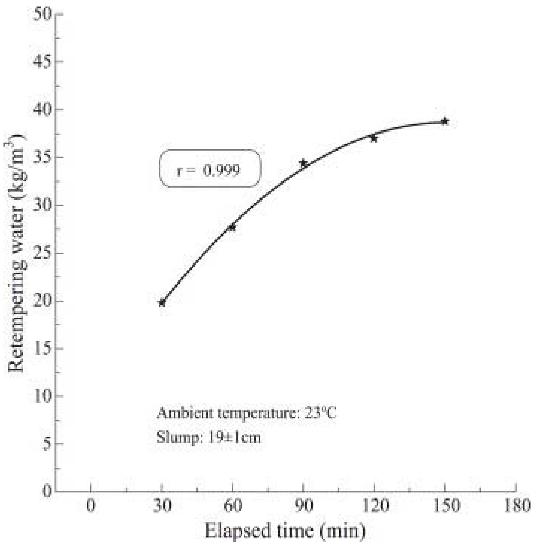

Fig2: water needed for retempering of concrete

***Admixture needed for retempering of concrete*:**
The relation between the amount of admixture used for retempering to restore the initial slump with respect to mixing time is given in Fig. 5 from appendix . As seen from the graph, the increase in the super plasticizer used for retempering is quite straightforward with mixing time and the relationship is statistically significant with a coefficient of correlation of 0.998. It is clearly seen that an additional super plasticizer of about 0.7% by weight of the cement content is needed at the end of a mixing period of 30 min for retempering to restore the initial slump of concrete, and it is only about 1.2% by weight of the cement at the end of 150 min of mixing. For a cement content of 300 kg/m3, the latter resulted in an addition of 3.6 kg/m3 of super plasticizer to the concrete mixture to restore its initial slump of 19 cm. The amount of super plasticizer needed for this purpose will surely be dependent on the specific properties of cement and the admixture–cement compatibility and the ingredients of concrete. It should be reminded that use of admixture could be logical as long as its effects are beneficial with respect to the strength development of concrete. Otherwise, particularly for economical aspects and possible adverse effects on concrete such as excessive amount of air entrainment, bleeding, and segregation; an engineering justification has to be made in terms of effective use of admixture

Figure: appendix fig3

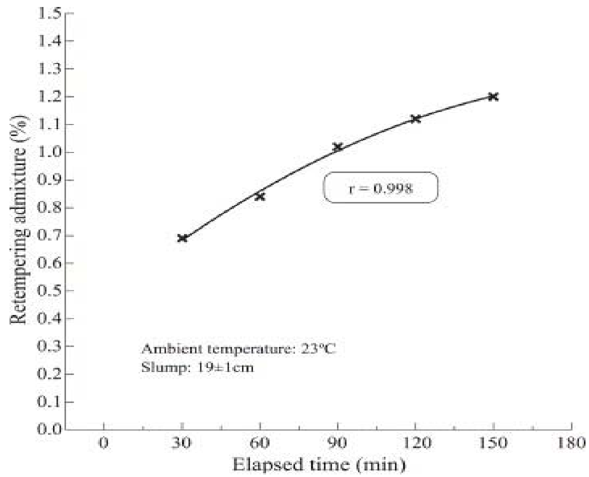

Fig3: Admixtures needed for retempering of concrete

Relation between retempering water and strength loss in concrete:
The stiffening of fresh concrete, and the associated slump loss, which is brought about mainly by the hydration of cement and evaporation of the mixing water due to prolong mixing, resulting in an appreciable reduction in the free water of concrete mixture. For full compaction, such concrete needs to be retempered using additional water to restore its initial slump. However, this is undesirable because additional water results mostly in an increase in the water to cement ratio and this in turn causes a substantial decrease in the strength of concrete. Fig.6 from appendix represents the relationship between the water needed for retempering of concrete and the strength loss in relation with mixing time. As seen from the graph, the relation increases linearly with a statistically significant coefficient of correlation of 0.946. In other words, the increase in the loss of strength is consistent with the retempering water used for restoring the initial slump of 19 cm. The relationship represents the results obtained from concretes subjected to a mixing period of up to 150 min at 30-min intervals. Regarding the relationship, for instance, a water addition of 30 kg/m3 for retempering caused a reduction in the strength of concrete slightly over 30% of its initial strength level. Undoubtedly, such a significant strength loss is of great importance with regard to the

sustainment of structural integrity and the performance characteristics of concrete.

Figure: appendix fig4

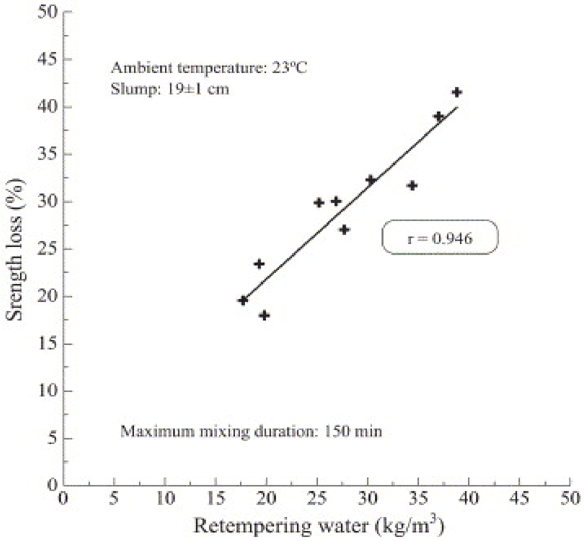

Fig4: Relation between retempering and strength loss

Effect of retempering on HCC Paste in concrete:

When water is added after hydration of the cement has begun and mixing is restarted, it commonly happens (especially in mixtures with a low w/cm) that the water is not distributed throughout the entire mixture, but is mixed only into the larger spaces between the aggregates. The material already adhering to the aggregates remains as a rim of darker material with a low w/cm around the aggregate particles and in the re-entrant angles. Patches of the original paste (unaltered by the additional water) may remain and can be found to be completely surrounded by the paste with higher water content. The problems of incomplete mixing are akin to the problems encountered in particular cooking situations. With gravy or white sauce, the thickening agent (such as flour) must be completely mixed with the cool water before the flour is affected by heat and begins to hydrate. If the flour and hot water mixture becomes too coherent, it may be impossible to add more water and create a smooth paste. The added water will mix with only a portion of the paste, and lumps of flour coated with stiff hydrated material will remain no matter how much mixing takes place.
Whenever water is added to the mixture without additional cement being added, the w/cm is raised. The higher the w/cm, the weaker the HCC. When more than the allowable amount of water for a given amount of cement is added to the mixture, the HCC will not have the designed strength. When the rims indicating incomplete mixing are present, a large portion of the cement can be concentrated in the thin bands of very rich paste around the aggregate and in the lumps of the original paste. The remainder of the paste is relatively depleted of cement and is thereby weaker than would be expected from the w/cm calculated from the originally delivered mixture plus the additional water. Thus, it can be seen that areas of HCC with a high w/cm can exist in close proximity to areas with a low w/cm.It must be remembered that any material is only as strong as its weakest zone. Stress in HCC in service or in a testing apparatus will cause cracking. Cracks will always follow the zones of weakness. In HCCs that have paste areas with different w/cm's, the cracks are going to develop in the areas of higher w/cm and thus the strength will be dependent on the extent and continuity of those areas. The skeptic will mention the fact that the bond between the aggregate and the paste in many HCCs is the weakest area and say that the dark rims of high cement content eliminate this problem. Although this is true, the fact that weak bond areas are not as continuous throughout the paste as are the light-colored areas with a high w/cm (low cement content, high water content) obviates the value of rims with a high cement content as bonding agent.

Effect of retempering on air voids in concrete:

Quantity: When retempering has occurred and the mixing has not been completed, petro graphic examination will show that many portions of the paste have a much higher void content than does the HCC of the rims and dark patches. Thus, the weakness of the portion with a high w/cm is compounded by the portion containing more than its proportionate share of air voids. In moderate cases, the spacing factor of the air-void system may change very little because the spacing factor is most dependent on the very small voids. Pigeon, et al. (1990), reported that there was little change in the spacing factor in the mixtures they studied if the retempering did not increase the slump by more than 100 mm.

Shape: When remixing takes place after some coalescence of the HCC has occurred, the remixing may occur after the individual integrity of some of the small air voids has formed. In such cases, many of these voids will retain their surface area, but lose their original spherical shape and become ovoid, or squashed, or develop an angular shape

***Size*:** Retempering can cause an increase in the size of air voids, the number of air voids, or both. The size of the voids caused by retempering as evidenced by the microscopical examination shows that the larger voids (more than 1 mm across) nearly all occur within the portion with the higher w/cm. In normal, well-proportioned HCC, the percentage of voids whose diameter expressed on the surface examined exceeds 1 mm should be less than 2 percent of the total concrete.

Effect of retempering on compressive strength subjected to prolonged mixing:

The effect of mixing time on the strength of reference concrete with no retempering.A slight increase in the strength of reference concrete is observed due to the increase observed in its unit weight. The total increase in the unit weight of reference concrete with no retempering is about27 kg/m3 which corresponds to a decrease in the air content of concrete slightly over 1%. This in turn reflects basically an increase of about 15% in the strength of concrete at the end of 150 min of mixing. This can mostly, but not completely, be attributed to the decreased air content of Concrete, as known, is reduced during prolong mixing. Although it seems to be usually negligible in the laboratory climatic conditions, evaporation of free water in concrete in

Conjunction with hydration of cement can also affect the strength of concrete favorably. This proves that concrete with low slump yields higher strength as long as it is placed and compacted properly as it is the case in the study. The strength of concrete retempered with water decreased sharply up to 90 min of mixing and then flattens out Resulting in a strength loss of over 40% at the end of 150 min in relation with its initial strength. This clearly indicates that the greater amount of free water in concrete results in the larger percentage of reduction in the strength of concrete.

Figure: appendix fig5

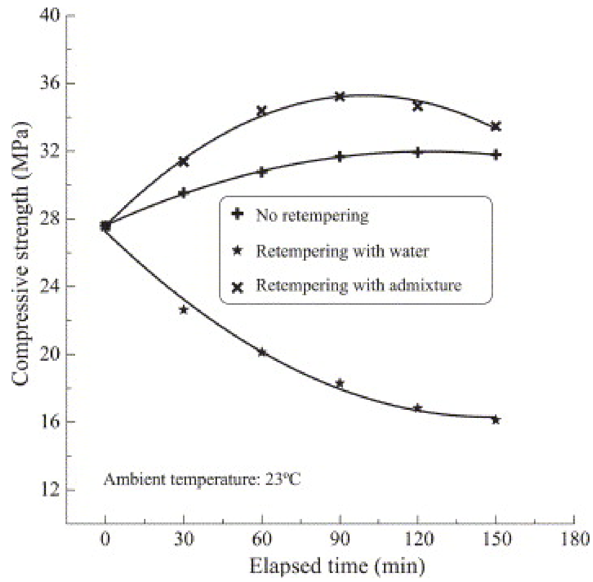

Fig5: Effect of retempering on compressive strength subjected to prolonged mixing

Effect of retempering on the compressive strength of ready-mixed concrete in hot dry environment:

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 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 specifications 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. Super plasticizer can be used instead of water to adjust slump. 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%. 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 (super plasticizers) is known to be an effective way to restore workability without adversely affecting other properties.

Figure: appendix fig6

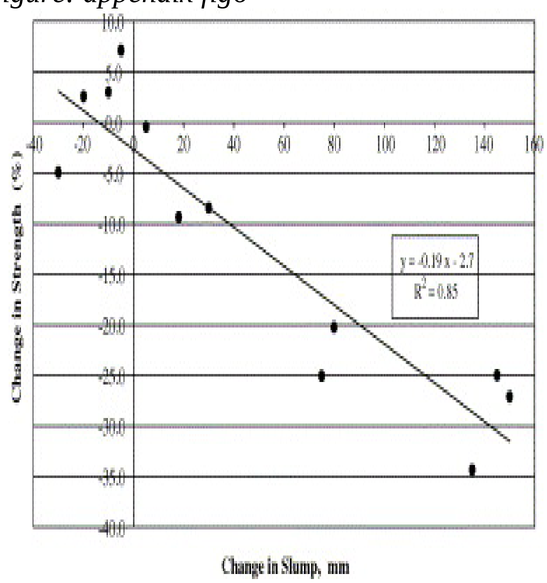

Fig6: Effect of retempering on the compressive strength of ready-mixed concrete

Effect of slump loss in retempering of concrete:

The effects of initial slump, temperature, and water-reducing admixtures on the loss of concrete plasticity with time were determined. Initial slump was varied by changing water-cement ratio. Slump was measured at 30 min intervals until a total mix and agitation time of 2 hr was reached. Concrete temperatures of 21 C (70 F) and 29 C (85 F) were studied. The initial slump values ranged from 8.9 cm (3.5 in.) to 19.1 cm (7.5 in.). The added water required to retemper concrete after 2 hr to a slump value of 8.9 to 10.2 cm (3.5 to 4 in.) was determined. The results of this study indicate for both reference and admixture concrete that slump loss is proportional to the initial slump level: the higher the initial slump, the higher the slump loss. Concrete containing conventional water-reducing admixtures allows a significant reduction in the total water required after retempering. The extent of this slump loss is proportional to the concrete age. For instance, the difference in slump loss between admixture and reference concrete is generally less than 1.3 cm (0.5 in.) at 30 min. In contrast, at 120 min., the difference is on the average less than 0.6 cm (0.25 in.). It is not desirable to compensate for expected slump loss in reference concrete by using a higher initial slump value since the retempered concrete will require a higher water-cement ratio.

Effect of retempering with super plasticizer on concrete in hot climate:

In hot climates, it may be necessary to retemper the concrete to maintain the required workability. The retempering is done by additional dosages of super plasticizer. However, there is a paucity of information on the effects of retempering at higher temperatures. Therefore, an extensive investigation was undertaken to determine the slump loss characteristics and effect of repeated retempering with super plasticizer on the strength and elastic properties of concretes mixed at ambient temperatures ranging from 30 to 60 C (86 to 140 F). A total of 15 concrete mixes with water-to-cement ratios 0.40, 0.50, and 0.60 were made at ambient temperatures of 30, 40, 50, 55, and 60 C (86, 104, 122, 131, and 140 F) to give constant workability. Immediately after mixing and after two retemperings at 30 min intervals, fresh concrete properties (slump, air content, concrete temperature, and unit weight) were determined. Specimens were cast after `days. The additional water and cement needed to achieve the same workability at higher temperatures is very high for low w/c concrete, whereas there is only a slight increase in the water demand for concretes with w/c 0.50 and 0.60. The increase in the rate of slump loss is not significantly higher at higher temperatures. When retempering with super plasticizer, there are no detrimental effects on fresh as well as hardened concrete properties even under the unfavorable high ambient temperature of 60 C (140 F). The performance characteristics are the same for concretes mixed at higher ambient temperatures and retempered with super plasticizer.

Steps for Prevention of retempering:

1. Cover or shade materials from direct sunlight, whenever practical. You can

avoid unnecessary retempering by keeping materials as cool as possible.

2. Sprinkle sand stockpiles with water to restore moisture and increase evaporative cooling.
3. Water stored in a light colored, open barrel is cooled to some extent by surface evaporation. Store the barrel away from direct sunlight.
4. Avoid using water from an unshaded water hose of any significant length. When exposed to sunlight, long water hoses become effective water heaters.
5. For extreme heat, add ice to the water.
6. Cool mixers, wheelbarrows, and other metal equipment by flushing with cool water.

Conclusion:

1) Retempering of RMC in hot-dry environments may result in substantial reduction in strength. When water was added solely to restore the slump within the specifications limits (100 ± 25 mm), the reduction of strength was below 10%. However, when the amount of water was added to increase slump beyond these limits, the reduction of strength may be as high as 35%.

2) In hot weather, the practice of retempering with water should be discouraged since super plasticizer can be used to adjust workability of concrete without adversely affecting other properties.

3) Less amount of water is needed when super plasticizer is used for the retempering process, as compared to the use of plain water alone. The final water–cement ratios of mixes retempered with super plasticizer are lower than that of mixes retempered with plain water alone. Thus, the decrease in the compressive strengths of those concretes retempered with super plasticizer is less than the decrease in the strengths of those concretes retempered with "plain water." Even slight increases are observed in compressive strengths of those concretes, which are retempered with super plasticizer (especially for the case of retempering with 4.5% super plasticizer).

4) The relationship between the retempering water and mixing time is of a parabolic shape with a statistically significant coefficient of correlation of 0.999

5) The relationship between the amount of admixture used for retempering against mixing time is quite straightforward.

6) There is a strong relationship between the water used for retempering and the strength loss of concrete. The relationship is quite straightforward with a statistically significant coefficient of correlation of 0.946. Based on the relationship, a water addition of 30 kg/m3 to the concrete mixture to restore the initial slump of 19 cm resulted in a strength loss of slightly over 30% with respect to its initial strength

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