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Effect of Mixing Speed and Time on Fresh Properties of Cement Mortar

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Abstract

Fresh properties of concrete are vitally important to make the well compaction in order to achieve the designed target of strength, serviceability and durability of the concrete structures. Fresh property of cement mortar (mortar) is generally judged by the workability and the air content. The workability refers to the compacting condition of the concrete which is directly related to the density and strength. The air content is required to maintain the durability of the structures especially minimizing the effect of freezing and thawing action. The workability, density and air content of the mortar are directly proportional to those of mortar for the given concrete mix. These parameters greatly depend upon the mixing speed and time of the mixer. This paper reports about the workability, densityand air content of the mortar mixed in the mortar mixer with varying of mixing speed and time. The workability of mortar was measured by the table flow test. It was concluded that there should be the appropriate combination of mixing speed and time to achieve the optimum fresh quality of mortar in terms of workability, air content and density.

***Keywords*:**Concrete;Mortar;Workability;Table flow test;Density; Air content

1. Introduction

Concrete is one of the most important construction materials in the modern engineering. It has very broad philosophy and its type can be altered according to the use in different fields of engineering. As for the good concrete, there are two over all criteria: the concrete has to be satisfactory in its hardened state, and also in its fresh state while being transported from the mixer and placed in the form work. The requirements in the fresh state are that the consistency of the mix be such that it can be compacted by the means desired without excessive effort, and also that the mix becomes cohesive enough for the methods of transporting and placing used so as not to produce segregation with a consequent lack of homogeneity of the finished product. The primary requirements of a good concrete in its hardened state are a satisfactory compressive strength and an adequate durability [1].

Concrete is very popular construction material and it is second to water being consumed in the world. However, the quality control of concrete is very difficult since it is the composite material of very different ingredients like cement, water aggregates and admixtures [2].The major problem of concrete is that although it is strong enough incompression, it is very weak in tension and ductility [3].

The compressive strength and other hardened properties of concrete greatly depend upon its workability for the sufficient compaction. K. H. Khyat evaluated the self-consolidated concrete (SCC) mixtures for slump flow consistency, restricted deformability and surface settlement, strength development, elastic modulus, temperature rise, shrinkage, permeability, and frost durability[4].

Presence of air content generally enhances the durability aspect of concrete. If the freeze-thaw durability of plain concrete is poor, it can be improved greatly when air-entraining agent is mixed into concrete. It demonstrates that ordinary strength concrete can also have high freeze-thaw durability [5].W. Sun et al. found that the addition of steel fiber or air entrainment or the combination of the two to concrete can improve its ability to resist damage[6].Concrete mixes with air contents of up to 12 percent still exhibit the same resistance to weathering as those in the 4 to 6 percent air range. The breaking point appears to occur at slightly over 12 percent, at which point durability begins to decrease markedly [7].The reduction of cement due to the increasing of air entrainment in the concrete mix results in a lower heat of hydration in mass concrete (dams as example). The decrease in the temperature, due to the hydration process, results in reduction of cracking and any undesirable internal stresses [8].The presence of entrained air caused a slight reduction in the water requirement, the flexural strength, and the dynamic modulus of elasticity of concrete, and increased the durability from 5 to 50 times, depending upon the quantity of entrained air and the coarse aggregate [9].Compressive strength of air entrained concrete decreased when admixture percentage increased. Split tensile strength also decreased when percentage of admixture increased [10].

Despite of using appropriate proportion of ingredients or adding any admixtures, mixing is one of the most important factors to provide the designed workability and air content of the concrete.It is essential that the mix ingredients are properly mixed so as to produce fresh concrete in which the surface of aggregate particle is coated with cement paste and which is homogenous on the macro-scale and therefore possessing uniform properties [11]. It has been claimed that very high intensity mixing can result in better workability and higher strength concrete [12]. However, it should have some optimum level for both of the intensity magnitude for given time or the time for the given intensity, from which the quality may not alter for some instant and then may start the segregation of ingredients. Uomoto has revealed its optimum level for some main properties of concrete [13]. To improve the mechanical interface between the aggregate and the cement matrix, as well as the surface quality of concrete grains themselves, various mixing techniques are investigated, such as the two-stage mixing and the three-stage mixing [14,15].

Mixing time and the speed are inter-related terms for the energy to be required for stirring of the materials in order to make them well dispersed and giving uniform distribution of each constituents present. Mixing speed can be defined as the speed at which the mixer operates. It can be measured in different index depending upon the nature of mixers, i.e. drum rotating speed, axis revolving speed etc. Mixing time is defined as the time required for mixing which is measured after the finishing of charging the mixer with all components of the mix to the time of discharging. The detail study on the type of mixers and mixing time was carried out by Kishi et al. [16].

Since the workability and air content of the concrete is directly proportional to that of mortar, the author has attempted to determine the appropriate combination of the mixing speed and time for the workability, density and air content of the fresh mortar.

1.1. Objective

The main aim is to experimentally investigate the effect of mixing speed and time on the fresh properties of mortar. Its specific objectives are:

(1) Evaluate workability, density and air content of fresh mortar in the different combination of mixing speed and time.

(2) Determine the appropriate combination of mixing speed and time for the optimum values of workability, density and air content of the fresh mortar.

2. Materials and procedure

Type I Ordinary Portland Cement with its specific gravity (sg) of 3.15 was used. Fine aggregate was crushed type (sg=2.67). Types of plasticizer and air entrained agent(AE agent) were No.70 and 303A respectively.The type of mortar used in this investigation was that of Dam-A type concrete. The plasticizer No. 70 was 0.25% by the weight of cement and the air entrained agent 303A was 0.02% by the weight of water.

Table 1 gives the basic mix proportion of the mortar used in all series of experiments.

Table 21 Mix proportions of mortar

Mix proportion conditions			Unit weight content (kg/m^3)			No. 70 (gm)	303 A (gm)
Mix Type	W/C (%)	C/S	W	C	S		
Dam-A	48.7	2.47	262	538	1329	1345	53.8

2.1. Mixing procedure

The mortar mixer of 10 liter capacity was used for the mixing work. The volume of each batch was 6.7 liter. The major parameters for mixing speed were chosen as medium speed and slow speed of the mixerof 12 rpm. The parameters of mixing time chosen for each mixing speed are given in Table 2.

Table 2 Mixing speed and time

Mixing Speed	Mixing Time (secs.)
Slow	30
	50
	70
	90
	120
	180
Medium	20

	40
	60
	120

The content of sand and water was adjusted with pre-measurement of moisture content of sand and the content of admixtures (both admixtures were in liquid form).

The plasticizer and AE agent were pre-mixed with water in the bucket prior to pouring into the mortar mixer. The solid ingredients were charged into the mixer in sandwich layer (half content of sand at top & bottom and full content of cement at middle). Then, the water was poured and the mixing was started. The mixing speed and time were maintained as according to the parameters given in the **Table 2**. Then the mortar was ready for the tests.

After the finishing of mixing, the ambient temperature and that of mixed mortar were noted. Table flow test was carried out as prescribed by the Indian Standard [17]. The maximum and minimum diameter of the flow was measured and the average value was taken as the table flow value. The air content test was carried out using the air meter as according to the Indian Standard [18]. The density of the fresh mortar was also measured while carrying out the air content test. First of all, the weight of empty measuring bowl was weighed. After feeling the mortar into the bowl and finishing, with specified procedure, the bowl with concrete was weighed. The difference of weight was taken as the weight of the mortar. Then the weight of mortar divided by the inner volume of the bowl was considered as the fresh density of the mortar.

3. Test results, analysis and discussions

All the test results are summarized in the **Table 3**.

Table 3 Test results on fresh properties of mortar

Mixing Speed	Mixing time (secs.)	Ambient temp.(^{o}C)	Mortar temp.(^{o}C)	Table flow (mm)	Air content (%)	Fresh density (gm/cm^3)
Low	30	28.0	29.5	220	6.2	2.19
	50	28.0	29.5	228	7.4	2.14
	70	28.0	29.5	232	8.0	2.10
	90	28.0	29.5	238	8.6	2.08
	120	27.0	29.0	237	8.8	2.07
	180	27.0	29.0	228	7.0	2.16
Medium	20	28.0	29.0	231	7.4	2.17
	40	28.0	29.5	236	8.3	2.11
	60	28.0	29.5	238	8.7	2.09
	120	28.0	29.5	228	7.2	2.14

Fig.1 shows the relation between the table flow value and the mixing time for the two different mixing speeds.As it can clearly be checked from the figure that the table flow value of mortar mixed with medium speed is higher than that from the low speed. For the mortar mixed with the medium speed, the optimum value of the table flow value (238 mm) was achieved at the mixing time of 60 seconds. However, it took the mixing time of 90 seconds to achieve the same value. After the optimum value, the flow started to decrease for the both mixing speed. It suggests us that the appropriate time of mixing should first be found with trial mixing tests in order to achieve the optimum value of table value for the available mortar mixer with designed speed.

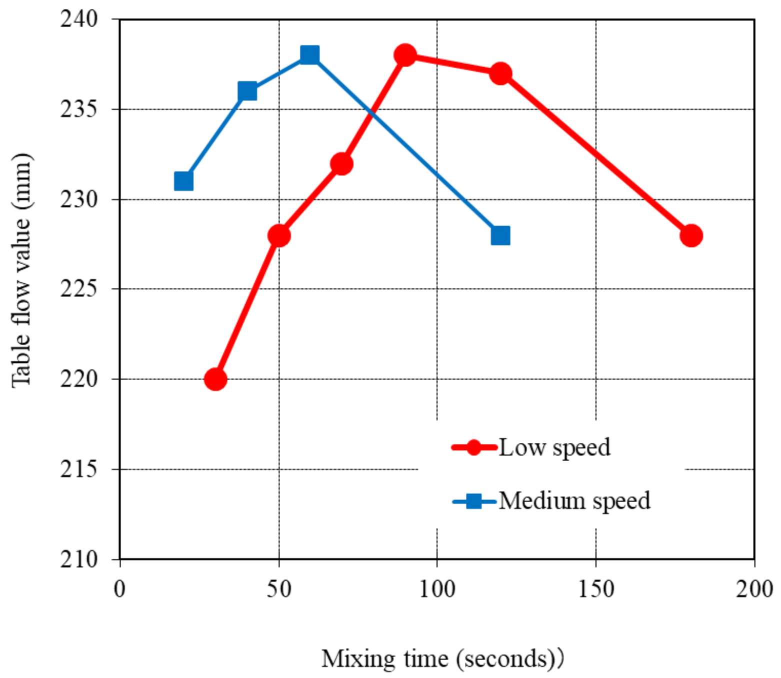


Fig. 1 Relation between the table flow value and mixing time of the mortar for different mixing speeds

The relation of mixing time and air content of the mortar mixed with two different mixing speeds is given in **Fig. 2**.

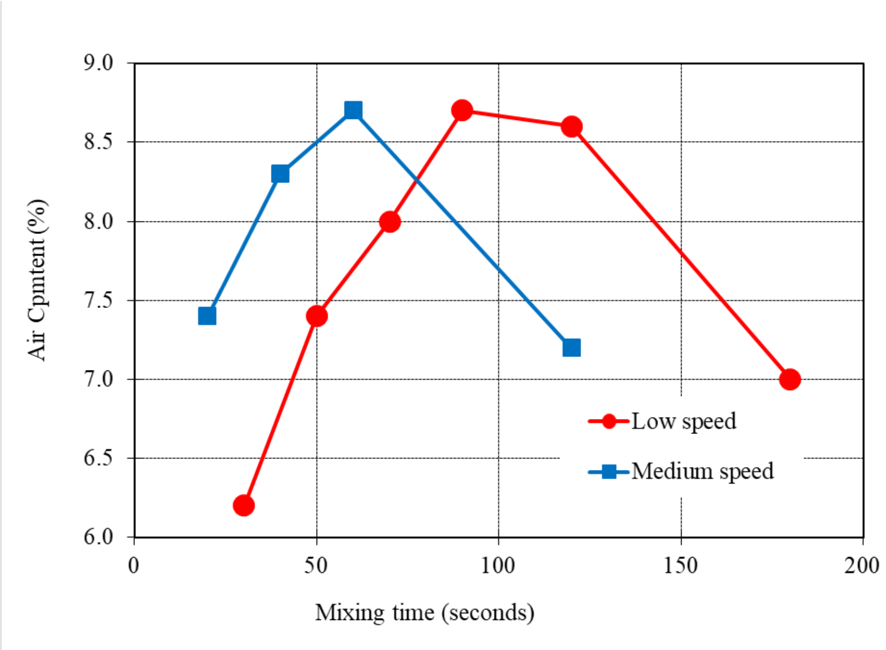


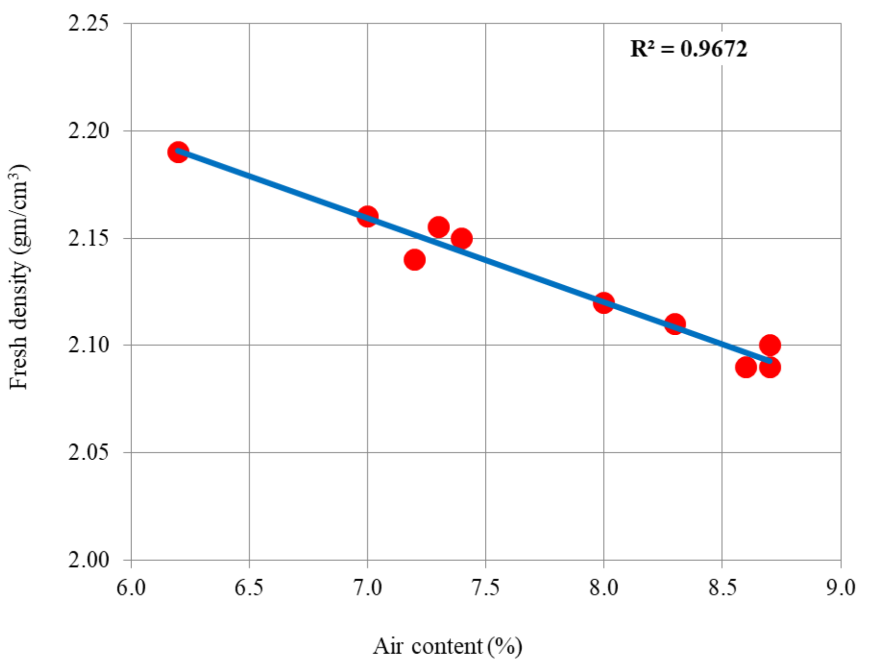
Fig. 2 Relation between the air content and mixing time of the mortar for different mixing speeds

The trend of the increase in the air content of mortar, with increasing in the mixing time, quite matches with the table flow value for the both different mixing speeds. Interestingly, the optimum value of the air content (8.7%) was obtained at 60 seconds of mixing time in medium speed mixing and 90 seconds at low mixing speed. It was also the same for the table flow test results. The air content also started to decrease, as in the table flow test, after reaching the optimum level.

The workability and the air content of the mortar are the key dominating factors for the easiness of the compaction and securing the designed durability of the structures. Although the workability and the strengths are two opponent properties of concrete, we should carefully match these properties in order to achieve the required properties of hardened structures. Since the mix proportion, with water cement ratio and unit water content, it is the most important work for engineers to fix the appropriate mixing time to obtain the optimum values of workability and the air content. The above both result suggest us that the optimum value of the workability and air content can be achieved at the same mixing time for any commercially available mixer.

The analysis work was carried out to judge if obtained data were reliable enough to respond the conclusion. It was mainly judged with the relation between air content and fresh density.

Fig. 3 shows the relation between the fresh density and air content of the fresh mortar. The graph clearly shows that the fresh density of the mortar is linearly decreased with increase in the air content (with $R^2 = 0.9762$). It satisfies the theoretical aspect of the relationship between the fresh density and air content of the mortar/concrete.



And in another consideration on fresh properties of mortar/concrete, the increase in air content also increases the workability linearly. It is also experimentally verified by the experimental results shown in **Fig. 4**. The table flow of the mortar is almost linearly increased while increasing the air content. The regression linear line quite matches with the experimental results with $R^2 = 0.957$.

Moreover, the regression line drawn with experimental results in the relation between the fresh density and table flow value also shows that the fresh density of mortar linearly decreases while increasing the workability (table flow value) of the mortar. The value of $R^2$was found 0.9013 representing that some data might have scattered due to some error during compaction process.

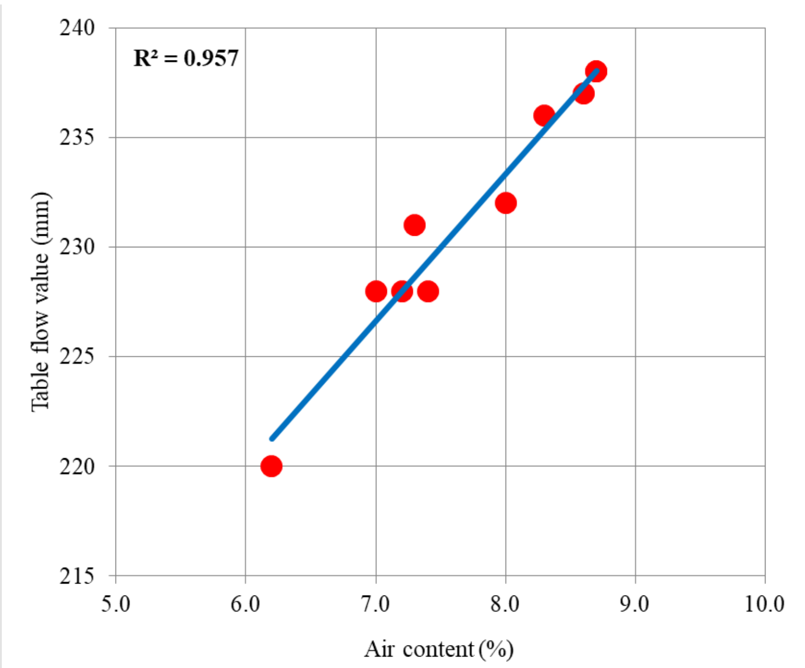


Fig. 5 Relation between Table flow value and air content of mortar

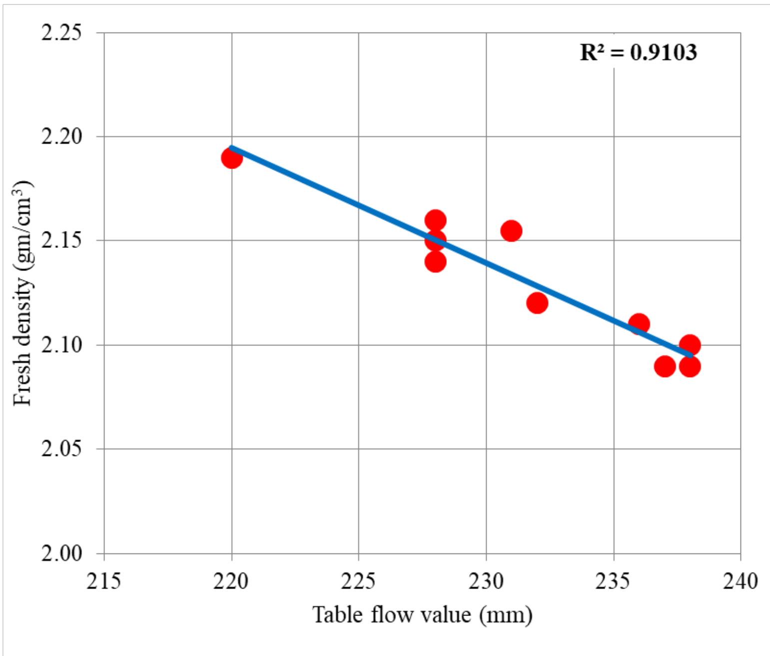


Fig. 6 Relation between fresh density and table flow value of mortar

The result shown in the **Fig. 5** – **Fig. 6** has backed up the result on the identification of the appropriate mixing time for the optimum result on workability and the air content. All of these experimental results have been satisfied with the theoretical considerations on fresh properties of mortar. It is also understood from these figures that the relation between two of these three key parameters (workability, air content and fresh density) always exists despite of different mixing speeds and times. It is because these parameters mainly depend upon the mechanical energy developed during the stirring of mixer. The mechanical energy can be taken as the function of electric consumption during the whole mixing. Thus, the mixing performance of any concrete or mortar mixer to achieve the optimum level of fresh properties should be analyzed based upon mechanical energy or electric consumption. It simplifies the methods to evaluate the mixing performance of commercially available mixers in the market.

4. Conclusions

The following main points were drawn from the series of this experimental study.

- Workability, air content and fresh densities are the key parameters to define the properties of fresh mortar/concrete, which indirectly handle the hardened and durability properties of concrete structures.
- The appropriate mixing time to achieve the optimum level of fresh properties was 90 second for low mixing speed and 60 seconds for medium mixing speed.
- The analysis of the experimental result satisfactorily satisfied the inter-relation between the key parameter. It helped to verify that the experimentally determined mixing times for two different mixing speeds were reliable.

- Despite of different mixing speed and time, the inter-relation between key fresh properties always exists.
- It is recommended that it is better to judge the performance of mixer based on mechanical energy or electrical consumption. It will simplify the method for judging the mixing performance of the commercially available mixers.

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Conflictof Interests

The author declares that there is no any conflict of interest regarding this publication.

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