Variation in Fineness of Portland Cement and its Effects on Properties of High Strength Concrete

L.A. Qureshi[1], A. Jawad[1], I.A. Bukhari[1], M. J. Munir[2]
[1]*University of Engg. & Technology, Taxila, Pakistan,* [2]*Bahaudin Zakrya University, Multan, Pakistan*

1. ABSTRACT

This paper presents the effect of fineness of Portland cement (ASTM Type 1) on properties of high strength concrete (in fresh and hardened state). The objective of this paper is to see the response of high strength concrete with different levels of cement grinding keeping other factors constant. First of all concrete mix. design was carried out to produce high strength concrete. For this purpose high quality super plasticizer was used while cement used was of normal fineness as found in market. Then, fresh clinker having uniform chemical composition was collected from cement factory of same brand which was used in mix. design. Clinker was ground in laboratory in a ball mill along with 4% gypsum. Six samples with fineness ranging from 1525 to 3741 cm^2/g, each weighing 15 Kg, were prepared. British Standards were followed during this investigation. Uniform chemical composition of each sample was confirmed by cement spectroscopy. 150 mm ($6^{//}$) cubes were cast according to already done mix. design and tested for compressive strength at the age of 3, 7 and 28 days. For workability of concrete, slump and compacting factor tests were performed for each mix. Graphs were drawn between fineness of cement and properties of fresh and hardened concrete. While grinding clinker with gypsum, time taken by the ball mill in preparation of different samples was also noted. These values of time were plotted against respective finenesses of samples. From the curve attained, comparative study of cost of grinding against desirable properties of high strength concrete at high fineness levels was made possible.

Keywords: fineness, clinker, compressive strength, workability, spectroscopy, slump.

2. Introduction

Fineness of cement, a property determined by the level of grinding of clinker along with gypsum in cement mill, has a significant effect on strength of cement. According to A.M. NEVILLE [1], PRICE [2], BUREAU OF RECLAMATION [3], KUHL [4], F. W. LOCHER et al. [5], and E. C. HIGGINSON [6], the rate of hydration depends on the fineness of cement particles and for a rapid development of strength high fineness is necessary. Also compressive strength increases with increasing fineness

but this increase ceases at higher finesses values. W. H. PRICE [2], H. C. ENTROY [7], and M. VENUAT [8] developed curves for 7 days, 28 days, 90 days, and 1-year compressive strength versus specific surface (Wagner), separately. They also showed that influence of fineness on strength varies with the water cement and concrete mix ratios. As per recent research**,** S. TSIVILIS [9], DALE P.BENTZ et al. [10], M.ONER et al. [11], also verified the previous results. However, D.P. BENTZ AND C.J. HAECKER [12] gave an argument for using coarser cements in high performance concretes.

Unfortunately, very limited research is found on effect of fineness of cement on high strength concrete. This paper is aimed to investigate this effect. Cement samples of different finenesses were prepared in the laboratory keeping other properties like chemical composition, amount of gypsum etc, same. XRF-cement spectrometer was used to verify the chemical composition of cement samples. Cement clinker was taken from "**DG Cement Factory Dera Ghazi Khan"**, situated at 150 km aerial distance from Multan, a historical city of southern Punjab in Pakistan.

3. RESEARCH OBJECTIVES

1) No well-defined relationships exist between fineness of cement and properties of fresh and hardened high strength concrete. Therefore, this research work was planned to specify such relationship

2) Different codes impose different lower limits for fineness of cement. This research helps to determine the advantages and disadvantages gained, if actual fineness of cement violates these limits for high strength concrete.

3) The work of some researchers on effect of fineness of cement on high strength concrete was done on foreign cements. The trend of locally branded cements manufactured by using indigenous materials was still demanding a lot of research work.

4. Preparation of Test Samples

1) Sufficient quantity of cement clinker having same chemical composition was collected from the factory, while the kiln was working smoothly. The clinker was brought to laboratory and stored temporarily in polythene bags.

2) Sieve analysis of this clinker as well as of gypsum to be mixed was carried out in the factory.

3) All clinker was crushed into smaller sizes by passing successively through two jaw crushers of different sizes.

4) Gypsum was also crushed into semi-powdered form by passing through the smaller sized jaw crusher.

5) The crushed clinker from above step (3) was mixed with 4% gypsum from step (4) and finely ground in iron-jar type ball mill at different fineness levels in the laboratory.

6) After continuous grinding, the following samples were prepared:

Sample	Fineness (cm^2/g)
F1	1525
F2	2065
F3	2495
F4	3048
F5	3355
F6	3741

7) During grinding of different batches, fineness was periodically checked by "**Blaine's air permeability apparatus**" and grinding stopped at different desired levels. The prepared samples were sealed in polythene bags and marked accordingly.

5. Experimental Programme

1) Chemical composition of all the samples were analysed by **XRF-Cement Spectrometer/Cement Analyser**. The chemical composition shown in Table-1 confirms the uniform oxide composition of all samples.

2) **Margala crush** was used as coarse aggregate. The following three sizes were used:

   A = ¾ in passing & ½ in retained.
   B = ½ in passing
   C = Pan
   A, B and C were mixed in the ratio of 4:3:1 to get a uniform grading conforming to BS 882:1992.

3) **Lawrencepur sand** was used as fine aggregate. Sieve analysis report for the same, conforms to BS 882:1992. The sand falls under the zone **"Fine Grading"**. **Fineness modules** come out to be **1.66**.

4) **High strength concrete** was developed by using the same brand of cement available in market (having fineness value of 2975 cm^2/g). Six trials were made to design the concrete mix. Concrete with **water cement ratio, 0.28** and **mix proportion of 1:0.75:1.75** with **1.7% by weight of cement super plasticizer** was selected.

5) 6 concrete mixes were prepared by using Mix. Design parameters but cement samples of different fineness prepared in ball mill.

6) Slump and Compacting Factor tests were carried out on each mix. to have an idea of workability of resulting concrete.

7) 12 concrete cubes (150 x 150 x 150 mm) were prepared from each mix. (Total 72).

8) 3 cubes from each mix. were tested for compressive strength at the ages of 3, 7 and 28 days respectively by adopting BS 1881: Part 108 :1983.

Table 1: Chemical Composition of Test Samples

Sample	Fineness (m^2/kg)	Chemical Composition (%)									
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	SO_3	K_2O	TiO_2	Mn_2O_3
F1	1525	21.42	5.30	3.14	62.85	1.83	0.24	2.63	0.86	0.31	0.04
F2	2065	21.58	5.29	3.15	63.28	1.79	0.23	2.67	0.85	0.32	0.04
F3	2495	21.48	5.26	3.13	62.85	1.77	0.24	2.60	0.84	0.31	0.05
F4	3048	21.60	5.37	3.20	63.27	1.79	0.24	2.72	0.87	0.32	0.04
F5	3355	21.54	5.33	3.16	62.85	1.80	0.24	2.64	0.86	0.32	0.04
F6	3741	21.55	5.35	3.18	62.98	1.80	0.23	2.65	0.86	0.32	0.05

6. Results and Discussion

6.1 Workability

Workability of different mixes was ascertained by slump and compacting factor tests.

6.1.1 Slump Test

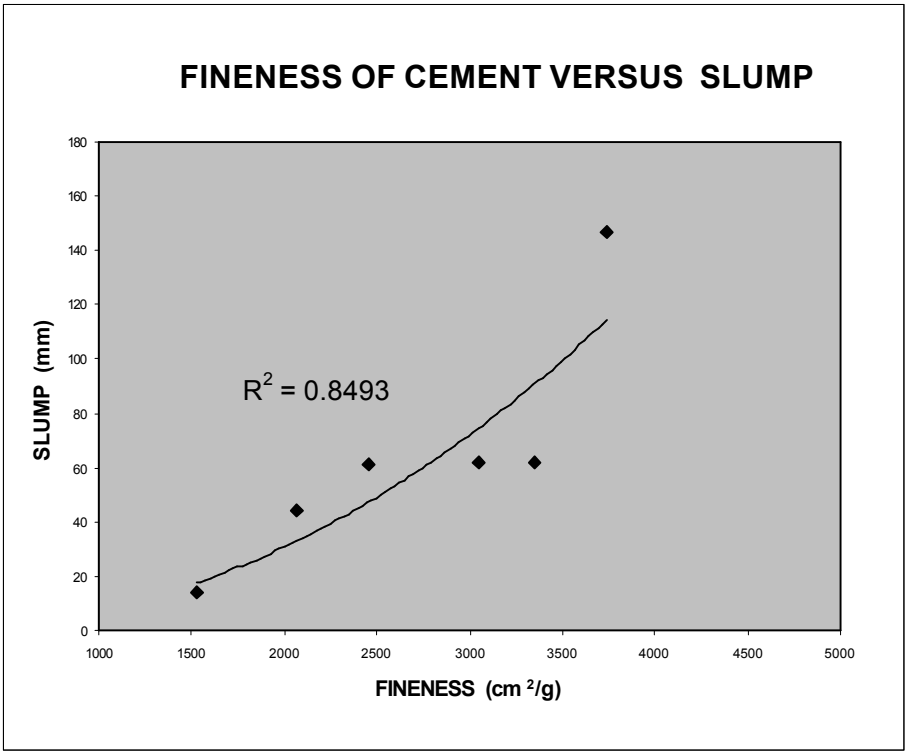

Figure 1

Slump test was carried out on all six mixes prepared by using cements of different fineness values as per BS 1881: Part 102:1983 or ASTM C 143-90a. Figure 1 show that slump increases with increasing fineness up to 2500 cm^2/g, then it remains constant up to about 3400 cm^2/g and afterwards, it again increases with increasing fineness. Figure 1 also shows the overall increasing trend of slump with increasing fineness.

6.1.2 Compacting Factor Test

Compacting factor test was carried out on all six mixes prepared by using cements of different fineness values as per BS 1881: Part 103:1993 and ACI 211.3-75. Figure 2 shows that compacting factor value also increase with increasing fineness of cement. However, there was no horizontal line observed at intermediate values of fineness, as was observed in case of slump.

Both test results show an increase in workability with the increase in fineness. It can be better understood with the fact that the increase in fineness is associated with increased cohesion and reduced bleeding. Also, very fine cements produce a fat and sticky concrete. In high strength

concrete, workability is controlled by a suitable water reducing agent. However, we can also take help from higher fineness of cement.

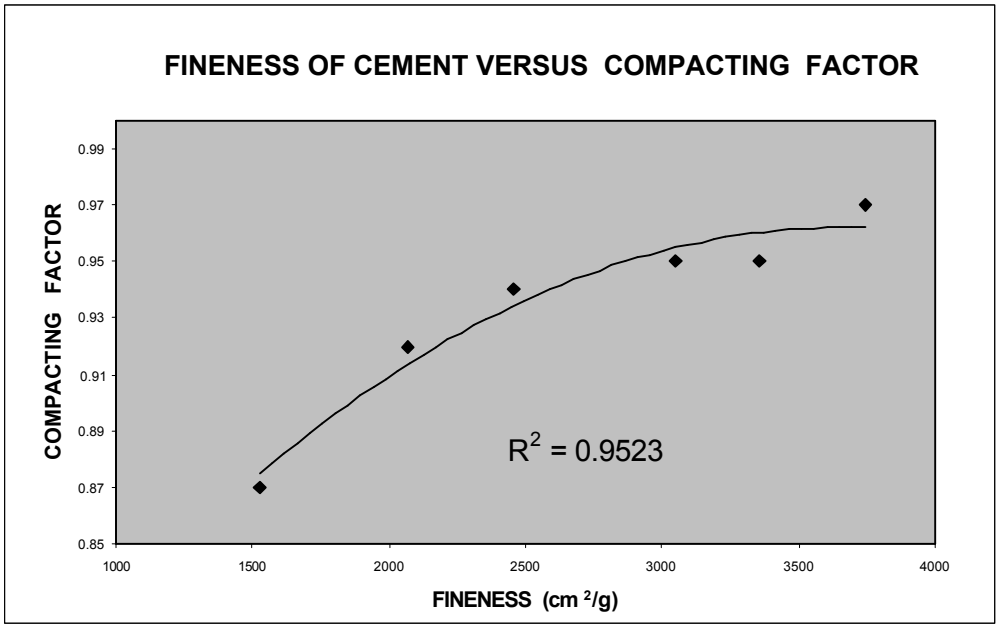

Figure 2

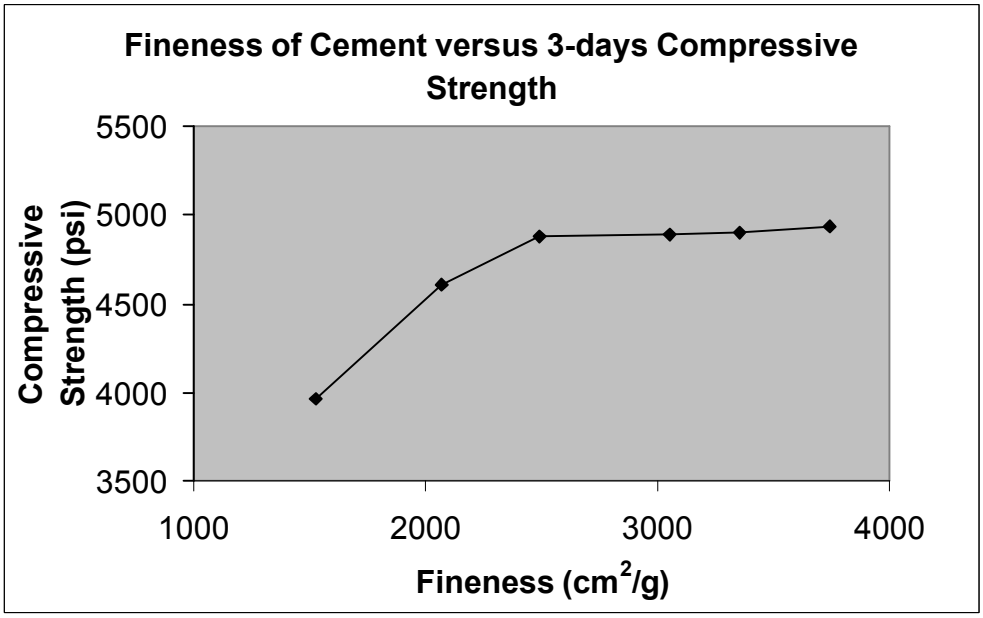

Figure 3

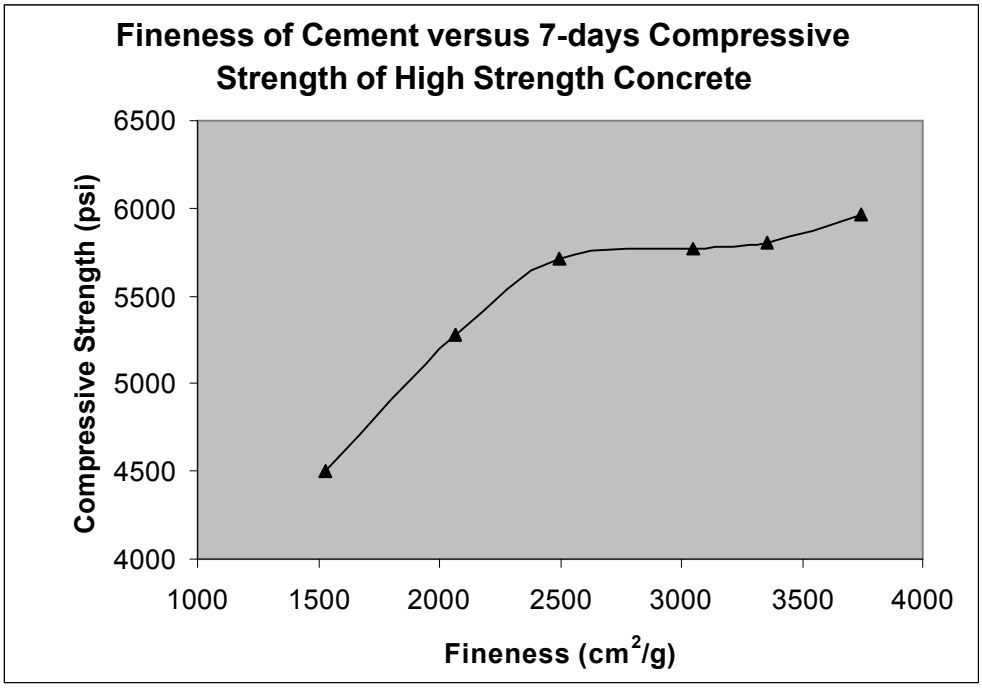

Figure 4

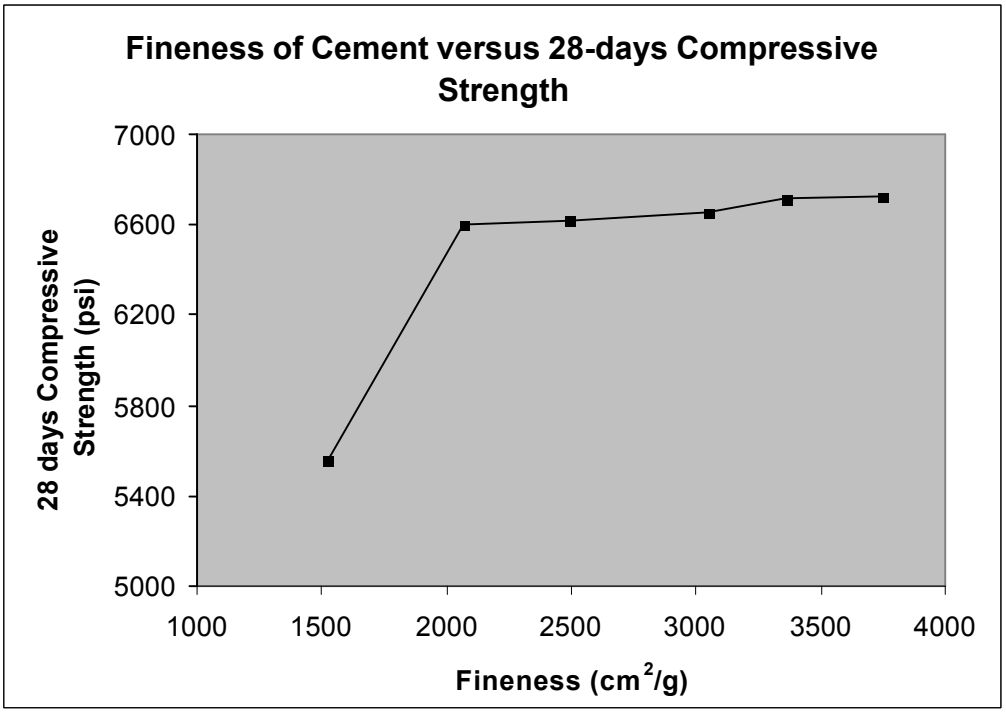

Figure 5

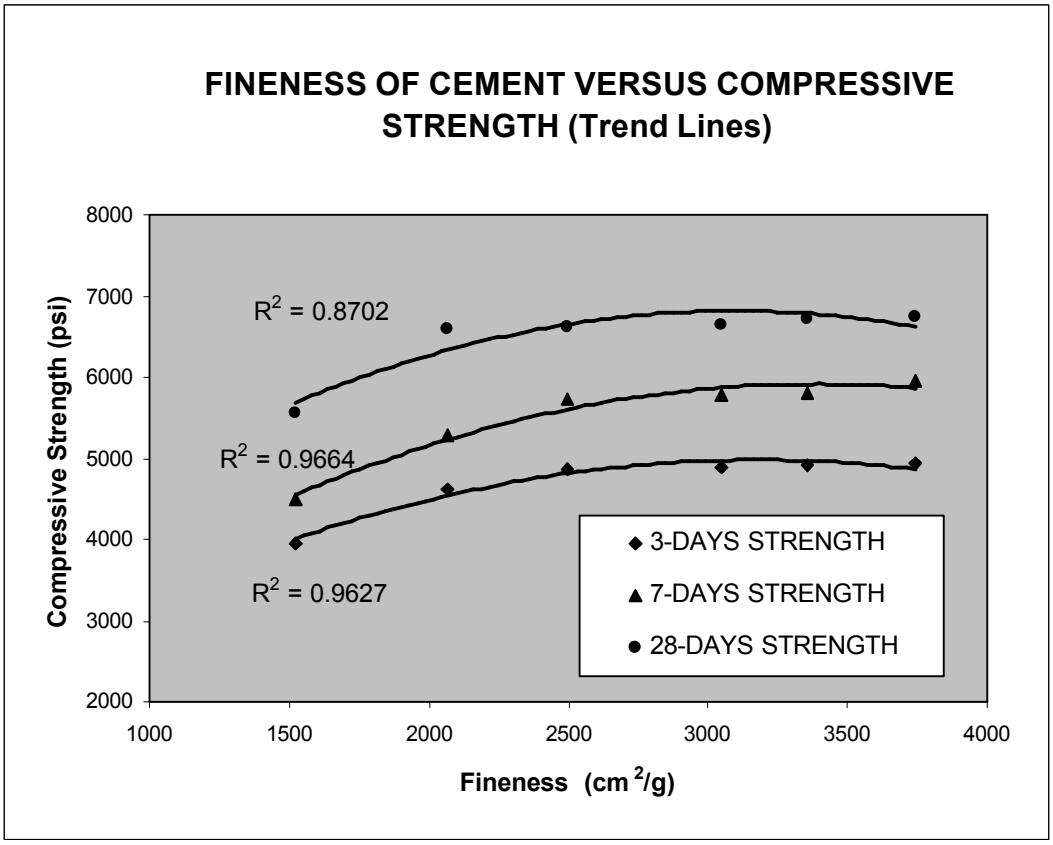

Figure 6

6.2 Compressive Strength Test

The compressive strength test was carried out on cubes cast from each mix. as per BS 1881:Part 108,111,116:1983 at the ages of 3, 7 and 28 days. Figure 5-7 show that there is an increase in compressive strength with increasing fineness. This increase is at higher rate up to 2500 cm^2/g, afterwards it ceases.

1) The increased fineness is associated with a greater surface area, which comes in direct contact with water. Hence, the rates of hydration, and the associated strength development, are increased.

2) Actually the effect of fineness on strength is greatest at early ages, decreasing with time as the hydration proceeds. At later ages, the cement grains are surrounded by dense CSH gel, which retards diffusion of water and thereby slows down the hydration process.

3) It is evident from figure 5 that if fineness of cement is much lowered than that used in Mix. Design, the concrete can not be designated as high strength concrete.

4) The best fitted curves between fineness of cement and compressive strength of concrete are drawn in figure 6 using **"Least Square Regression Method"** which proves that compressive strength of high strength concrete cubes at all ages increases with increasing fineness. Relationships for 3, 7 and 28-days strength and fineness of cement are found as under:

For 3-days Strength	$\mathbf{y = -0.0005x^2 + 2.8x + 2448.3}$
For 7-days Strength	$\mathbf{y = -0.0004x^2 + 2.7x + 1391.6}$
For 28-days Strength	$\mathbf{y = -0.0004x^2 + 2.25x + 1400.6}$

Note: In above relations, y and x stand for compressive strength of high strength concrete and fineness of cement respectively.

6.3 Grinding Time

Figure 7 shows the time of grinding involved in preparation of different samples. The curve is flatter at lower fineness levels, while it gets steeper at fineness goes higher. It means that more grinding cost is involved in manufacture of very fine cements.

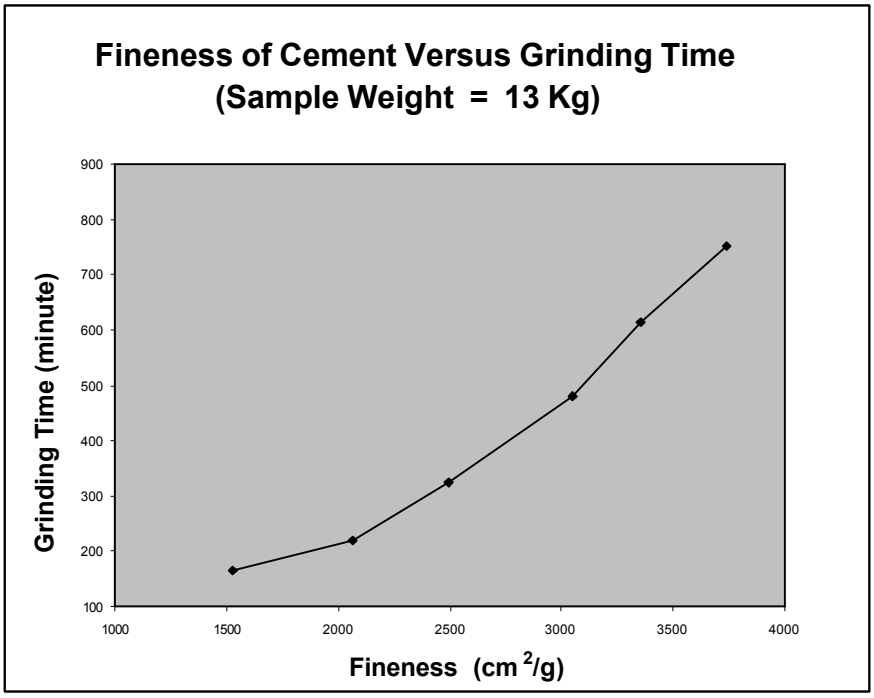

Figure 7

7. CONCLUSIONS

1) As the cement gets finer, an early gain in compressive strength is achieved. This gain in compressive strength ceases at higher fineness levels.

2) There is no effect in workability of concrete at intermediate fineness values. However, at high fineness levels, workability increases abruptly.

3) As cost of grinding increases non-linearly with increase in fineness, an optimum value of fineness may be searched out from project to project having a balance of enhanced compressive strength and cost of grinding.

4) Keeping in view the little benefit of increased compressive strengths with increasing fineness; it is not advisable to grind cement clinker indefinitely, as it will result only in an increase in the cost of production. Other measures may be adopted to get more workability with improved compressive strength of concrete.

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