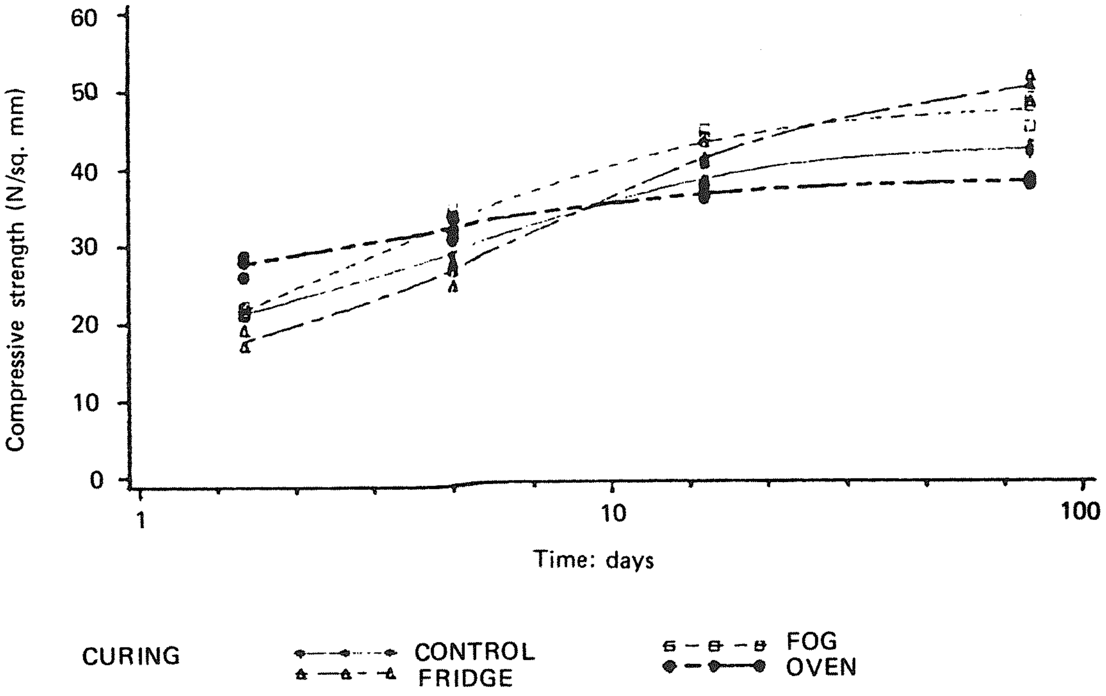

Fig. 5: Compressive strength at various ages for OPC3 concrete mix.

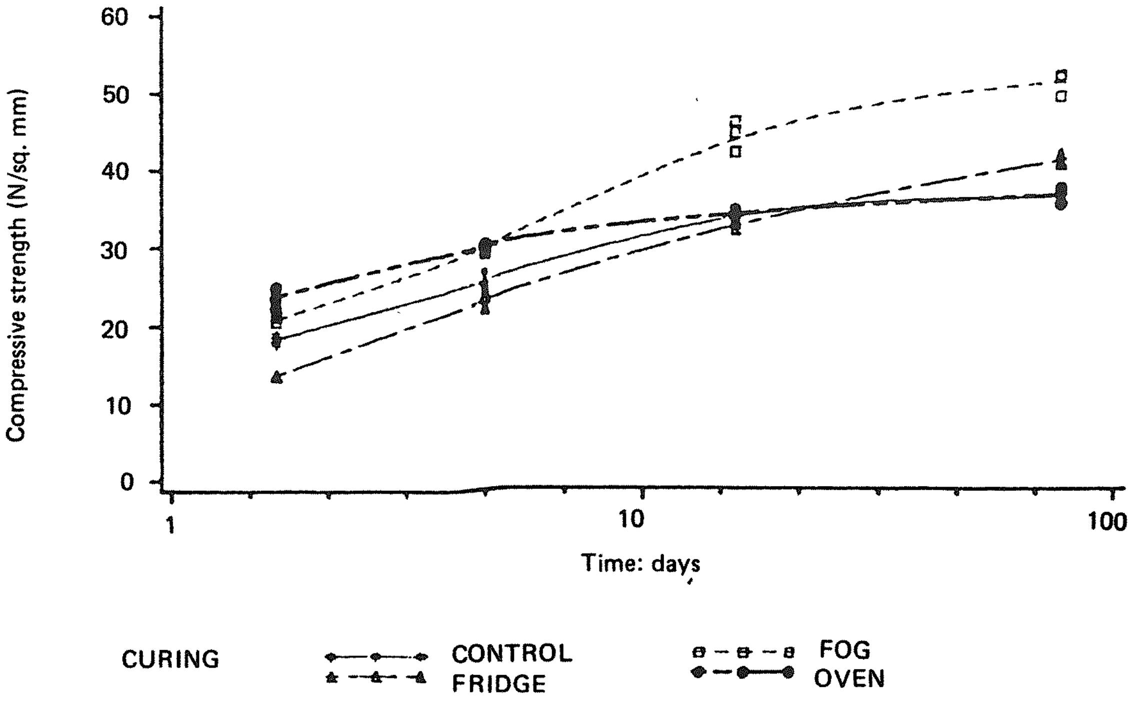

Fig. 6: Compressive strength at various ages for TR3 concrete mix.

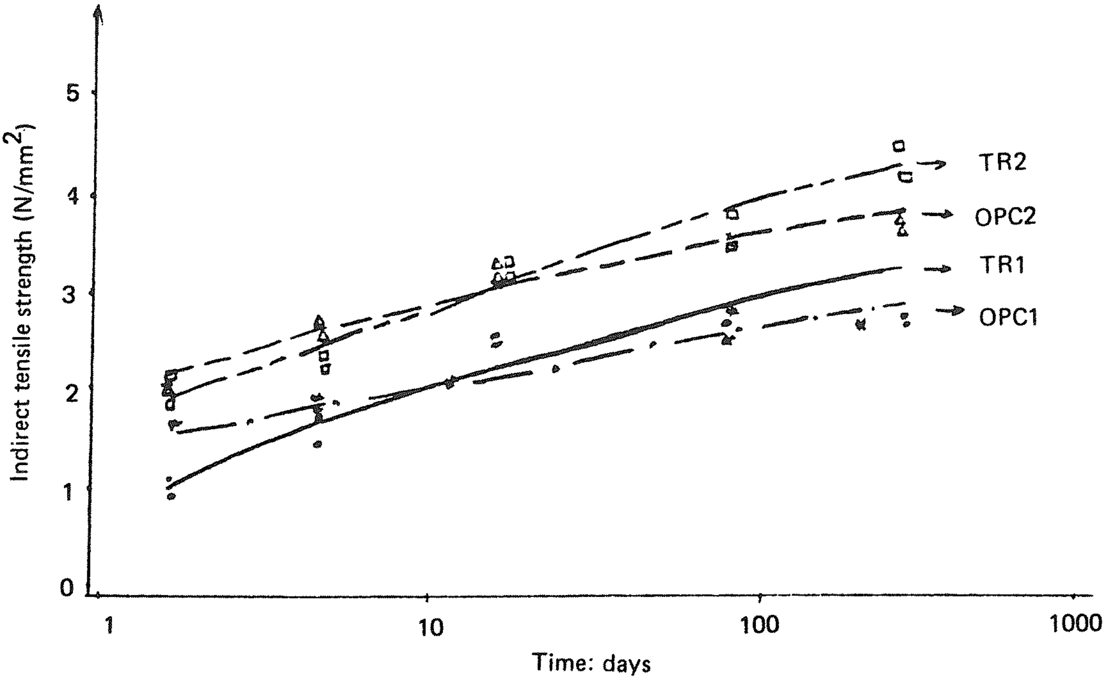

Fig. 3: Indirect tensile strength ages for OPC1, TR1, OPC2 and TR2 concrete mixes.

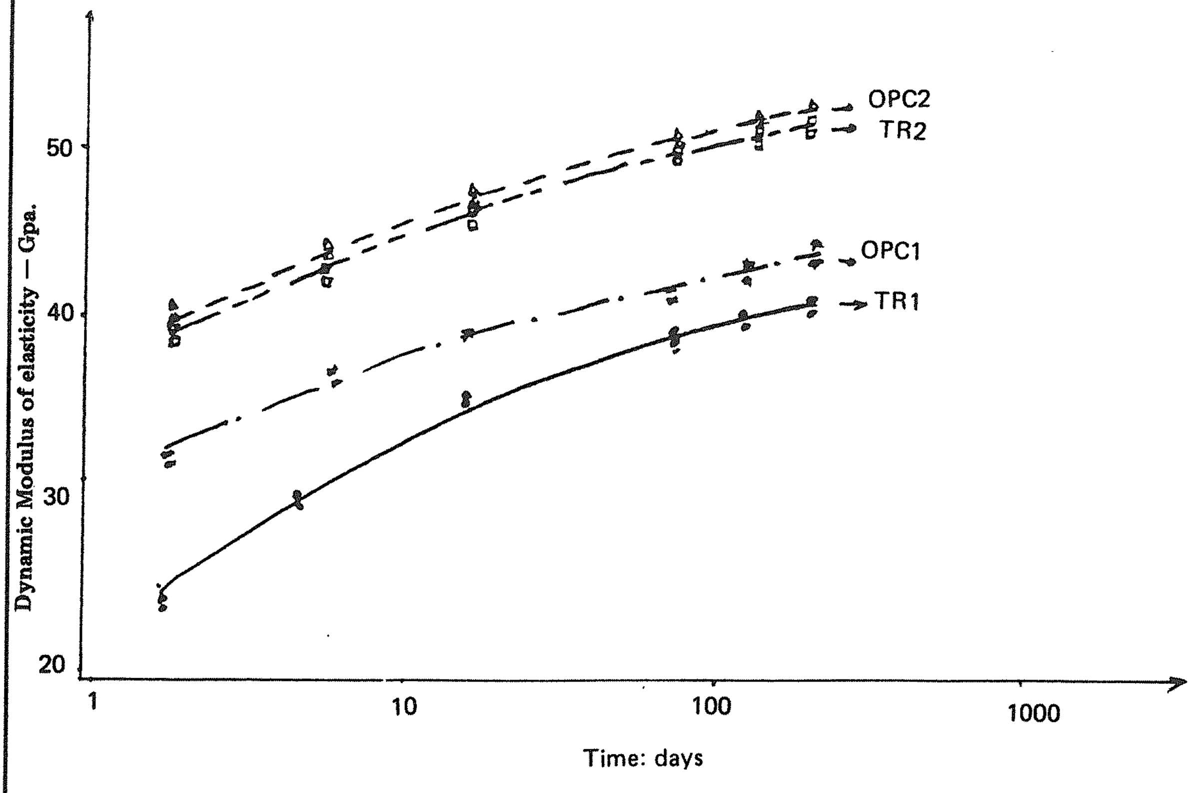

Fig. 4: Dynamic modulus of elasticity at various ages for OPC1, TR1, OPC2 and TR2 concrete mixes.

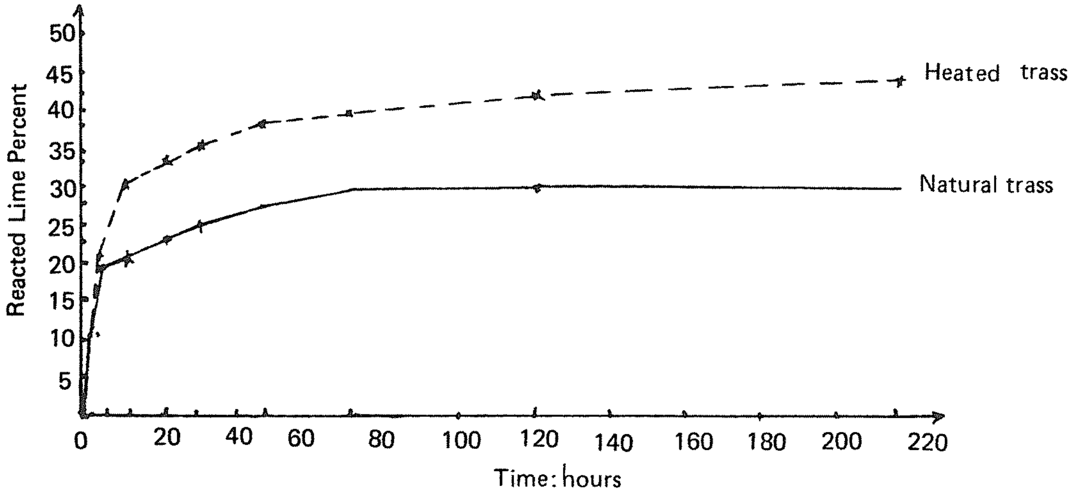

Fig. 1: Relation between consumption of lime and lime for material and heated tress

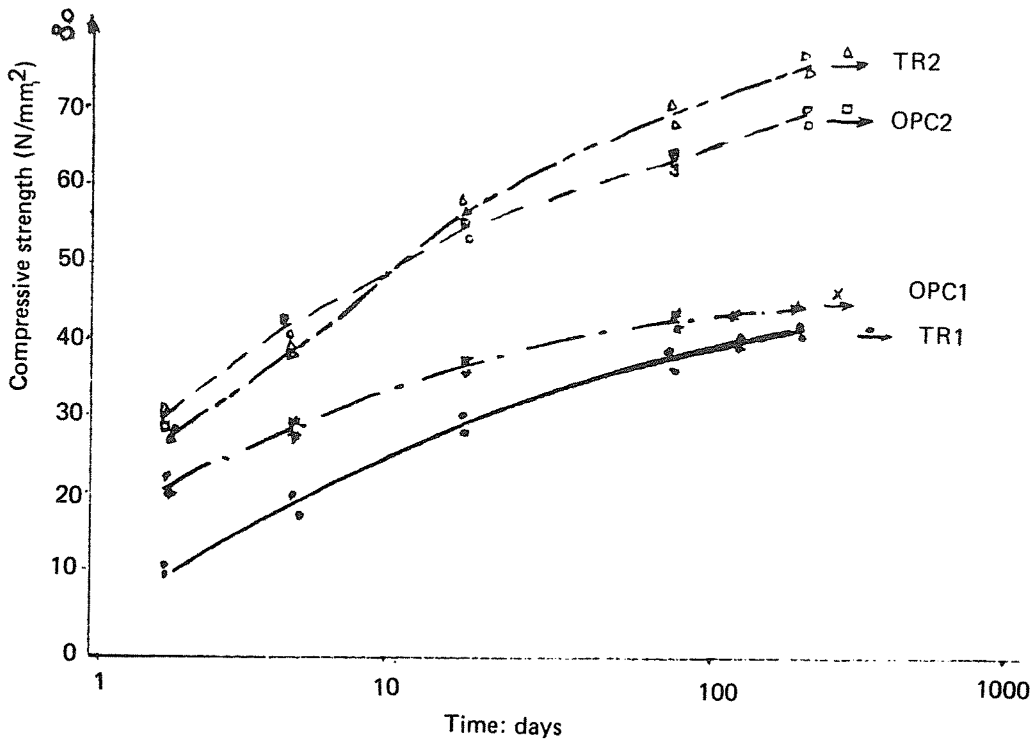

Fig. 2: Conpressive strength at various ages for OPC1, TR1, OPC2 and TR2 Concrete mixes.

CONCLUSIONS

The following conclusions are drawn from the results of this investigation on Portland pozzolan cements containing 20% trass:

The modified method which was used in this investigation for the assessment of pozzolanic activity of trass was found to be a relatively quick and promising method. The amount of lime consumption in heated trass was approximately 12% higher than that for natural trass confirming the changes on the pozzolanic activity of trass caused by thermal treatment.

On the basis of strength development data, It seems that trass did not make any contribution to the strength of cement. At longer ages due to the pozzolanic reaction of trass, the strength of OPC/TR concrete mix became greater than that for OPC Concrete mix with the addition of Superplasticizer - Similar. trends were found for compressive strength, tensile strength and modulus elasticity of mixes resulted in the introduction of models correlating these parameters. Comparison of the strength of OPC and OPC/TR mixes under 4 different curing regimes showed that curing at higher temperature improves the strength at early ages while at longer term curing under water or in fog room has the importantrole in this improvement specially for mixes associated with trass.

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The results of the compressive strength tests on concrete mixes are shown in figure 2. All the concrete mixes were designed to have 50mm slump. A higher demand of water in OPC/TR mixes to achieve this requirement resulted in a very low strength at early ages. Due to the higher surface area of trass particles and its fineness which required high water content, 20% cement was replaced by trass in this investigation. The result of 30% replacement of cement with trass has been published elsewhere[5]. As shown in figure 2 the strength of the concrete mixes increases with age. The OPC concrete mixes have shown higher strength than OPC/TR concrete mixes at early ages. At longer ages due to the pozzolanic reaction of trass mixes the difference is smaller and even the trass mix shows greater strength than OPC mix with the addition of superplasticizer.

The result of the indirect tensile strength tests up to one year is shown if figure 3. The trend in tensile strength gain is similar to that obtained for compressive strength. From the result of compressive strength and indirect tensile strength it would be expected that the two types of strength are highly related. Linear regression analysis was then carried out between the two strength. The following regression equations define the relationship between the compressive strength (fcu) and indirect tensile strength (f_{MR}).

For OPC1M mix $f_{cu} = 0.054\ f_{MR} + 0.556$ (r=0.974)
For TR1M mix $f_{cu} = 0.054\ f_{MR} + 0.556$ (r=0.984)
For OPC2 mix $f_{cu} = 0.047\ f_{MR} + 0.745$ (r = 0.974)
For TR2 mix $f_{cu} = 0.047\ f_{MR} + 0.745$ (r = 0.959)

It can be seen that in all mixes the indirect tensile strength is highly correlated with the compressive strength.

Results of the dynamic modulus of elasticity is shown in figure 4. The trend observed here is similar to the trend found in compressive strength. In order to relate the dynamic modulus of elasticity (E_c) of concrete to its compressive strength (f_{cu}), statistical analysis was carried out using the model described in the British Standard Code CPIIO. The following equations have been found for OPC and OPC/TR concrete mixes

For OPCI mix $E_c = 14.37\ f_{cu}^{0.33} - 7.27$ (r = 0.983)
For TR1 mix $E_c = 12.98\ f_{cu}^{0.33} - 3.87$ (r = 0.997)
For OPC2 mix $E_c = 12.84\ f_{cu}^{0.33} - 2.54$ (r = 0.993)
For TR2 mix $E_c = 11.12\ f_{cu}^{0.33} + 2.98$ (r = 0.992)

The results of the effect of curing on strength properties of OPC3 and TR3 mixes made at the same W/C ratio are shown in figures 5 and 6.

It is clearly seen that both OPC3 and TR3 mixes show the highest strength at 3 days in oven cured specimens when compared with the compressive strength of specimens cured in other curing conditions. It is interesting that after approximately 7 days, oven cured specimens show nearly the same strength as fog cured specimens and at 90 days compressive strength of specimens cured in those three other conditions is greater than the compressive strength of oven cured specimens. This is attributed to the effect of high temperature on quick hydration of cement at early ages and lack of moisture and low humidity in oven dried specimens at longer ages. In OPC3 mix, the compressive strengths of specimens cured in $5^{o}C$, oven and in the room controlled at $20^{o}C$ and 70% RH are nearly equal at 2 weeks. This equality in TR3 mix occurred after approximately 5 weeks. In TR3 mix, the rate of strength gain of fog cured specimens is greater than the rate of strength gain of those specimens cured in three other conditions. This reveals that how important is the curing conditions for mixes made with pozzolanic additives. The compressive strength of OPC3 mix is higher than TR3 mix at early ages for all curing conditions. This remains high at longer ages for all specimens except those specimens cured in the fog room whereby the compressive strength of TR3 concrete mix is greater than OPC3 mix at 90 days. This is due to the reaction of trass with the cement hydration products which takes place at a slow rate.

more water, a naphthalene formaldehyde based super plasticizer (Feb flow 2 supplied by FEB) in solid form was used.

Concrete Mixes

The composition of the concrete mixes used in the study is given in table 2. These were obtained according to the minimum porosity technique[3] and designed with the criteria of mixes of "constant workability". As can be seen from table 2 part of the mixes used in this investigation were made with the superplasticizer.

mix	sand	gravel	OPC	trass	superplasticizer	W/C
OPC1	2.33	4	1	–	–	0.61
TR1	2.33	4	0.8	0.2	–	0.69
OPC2	2.33	4	1	–	5×10^{-3}	0.51
TR2	2.33	4	0.8	0.2	5×10^{-3}	0.47
OPC3	2.33	4	1	–	–	0.6
TR3	2.33	4	0.8	0.2	–	0.6

Table 2: Composition of concrete mixes by mass

Mixing, Curing and Preparation of Specimens

Mixing of the concrete was carried out in a mixer of 0.1 m^3 capacity. The mixtures were cast into the moulds in two layers and vibrated by means of a vibrating table to remove any entrapped air. For each mix 18 cubes (100 mm), 2 Prisms (500 x 100 x 100 mm) and 12 cylindres (150 mm diameter and 300 mm height) were cast. All specimens were remained in their moulds for 24 hours at $20^oC \pm 1^oC$. After demoulding they were cured in a fog room at a termperature of $20^oC \pm 1^oC$ and 100% relative humidity. Some specimens were placed in a room controlled at 20^oC and 70% relative humidity (RH). In addition to these two curing regimes, samples of OPC and TR concrete mixes were placed at 5^oC, 100% RH and 45^oC, 50% RH to evaluate them in these conditions. The specimens cured in different conditions reaching the date of the test, i.e. 3 days, 7, 28, 90, 180 and 365 days were removed and tested in the same day.

Experimental Details

Pozzolanic activity-The pozzolanic activity of trass was assessed by measurement of the Activity Index using thermogravimetry. The method was originally proposed by Cabrera[4] and has been slightly modified for this work[5]. In this technique the amount of calcium hydroxide which was consumed by trass was measured at prefixed ages using a TG 750 Stanton thermogravimetric balance. Test was carried out on both natural trass and trass heated at 600^oC.

Strength and Elasticity- The compressive strength at 3, 7, 28, 90, 180 and 365 days was determined according to BS1881: Part 3[6] using 100 mm cubes. The indirect tensile strength was determined by using the split cylinder test. The procedure for this test is described in BS1881: Part 4[7]. The dynamic modulus of elasticity of concrete specimens was determined with the procedure described in BS1881: Part 5[8].

Test Results and Discussion

The results of lime consumption against time as obtained by using thermogravimetric analysis are presented in figure 1. All curves in this figure follow a similar trend of decreasing lime content with increasing time. It is clearly shown that lime is consumed at a fast rate in the initial stages of reaction (up to 2 days). After this period the rate of lime, consumption slows down sharply. It is seen that the total consumptions of lime after 2 days in natural trass and heated trass are 27.7 and 38 percent respectively while between 2 and 9 days the total lime consumption in the same mixes are only 3.9 and 7.7 percent respectively. Figure 1 also shows that heated trass has consumed more lime than natural trass. The amount of lime consumption in heated trass is approximately 11 to 12 percent higher than consumption of lime with natural trass. This has possibly occurred due to the disintegration of realistic minerals and formation of less stable phases.

Engineering Properties of mortars and concretes made with OPC and trass-OPC (Ordinary Portland Cement)

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ABSTRACT

A laboratory investigation into the properties and performance of OPC and trass-OPC mortars and concretes is presented.

A natural pozzolan of volcanic origin obtained from the Damavand area in Iran and knowas as "trass" is used to substitute 20% of the OPC content of mortars and concretes. The properties of the trass used include physical and chemical properties and also its lime reactivity in the natural state and after activation by heating up to 600°C. The engineering properties of the OPC and trass mortars and concretes are evaluated with respect to time.

INTRODUCTION

The need to save energy in energy expensive precesses like cement production requires an overall effort of optimization and also a reappraisal of the materials used. A wider use of pozzolans can go a long way towards solving this problem. It is also essential to have a durable concrete. Addition of pozzolanic material to a concrete mix can bring about a considerable improvement in the quality of the concrete and its durability. This paper is mainly concerned with the properties of a natural pozzolan knowas as "trass" and the engineering properties of mortars and concretes made with Ordinary Portland Cement and trass.

Materials And Experimental Details _ Materials:

The cement used throughout the test programme was Ordinary Portland Cement conforming to the requirement of BS12:1971[1]. The chemical oxide composition and some physical properties of the cement are given in table 1. The trass used in this work was green volcanic tuff obtained from the Damavand area in Iran where it is found as a natural volcanic sediment. The chemical oxide composition and the physical properties of trass are given in table 1. The sand used was quartzite sand conforming to the zone 3 requirements of BS882: 1983[2]. The coarse aggregate was a clean and well graded gravel with a maximum size of 20 mm. In order to make a concrete mix with a medium slump without adding

Material	Constituent, %by weight										specific surface m^2/g	specific gravity g/cc
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	TiO_2	SO_3	LOI		
OPC	20.9	5.5	2.7	64.3	2.5	0.3	0.8	–	2.8	0.7	0.38	3.15
trass	76.8	12.8	1.1	2.6	1.3	1	2	0.1	–	0.2	15.86	2.22

Table 1: Oxide composition and physical properties of the cementitious materials