DESIGN AND TESTS OF LOW SHRINKAGE CONCRETE FROM LOCAL MATERIALS

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ABSTRACT

Shrinkage is the reduction in volume of concrete due to varying factors both intrinsic and external. The symptomatic evidence of shrinkage is cracking. Cracks is a sign of poor concrete quality and unwanted by both the client and the designer.

In the course of this study, it was discovered that shrinkage of concrete could be minimized by using suitable constituent materials and mix proportions. Adequate moist curing is also essential to reduce the effect of any volume changes.

1.0 INTRODUCTION

Concrete is a construction material made by mixing cement, coarse aggregate (gravel, crushed stone), fine aggregate (sand), and water either in a designed or prescribed proportion depending upon its structural requirement. The quality of concrete is determined by that of its constituent materials. It is desired that concrete produced at any given instance should among other qualities have satisfactory durability in the environment which the structure is placed and satisfactory appearance in those situations where it is exposed to view. For this to be possible the susceptibility to shrinkage should be minimal. Shrinkage is the reduction in volume of concrete as a result of varying factors, both intrinsic and external. The symptomatic evidence of shrinkage is cracking. Cracks occur when the stress induced by the free shrinkage strain, reduced by creep is greater than the tensile strength of the concrete.

Woodward, (1956), says: "Probably the most annoying aspect of concrete construction is that of shrinkage - a change in volume due to set." Cracks are an eyesore, first to the owner who usually interpretes them as a sign of weakness, poor concrete and imminent collapse and second to the engineer, who interpretes them as poor concrete quality, over sight in design considerations, or just another contribution to his frustrations. It is rare if not mythical to have concrete that has no shrinkage cracks. Generally speaking if you have concrete in any large volume you are sure to have some cracks. To keep them to a minimum in size and extent is the goal.

2. BACKGROUND INFORMATION

Concrete like other materials is subject to changes in volume. When the environment and forces acting cause reduction in the volume of concrete shrinkage is said to occur otherwise the concrete experience swelling. Shrinkage of concrete could be plastic, autogenous or drying depending on the period during the life time of the concrete they manifest themselves.

Plastic shrinkage manifests itself soon after the concrete has been placed in the form. It has been found out that the magnitude of this type of shrinkage is of the order of 1% of the absolute volume of dry cement (SWAYZE 1943). Preventive measures are usually based on methods of reducing water loss. This can be achieved in practice by covering concrete with polythene or by spraying with a membrane curing compound.

Autogenous shrinkage as the name implies is self produced by the Hydration of cement. Several factors influence the rate and magnitude of autogenous shrinkage. These include the chemical composition of cement, the initial water content, temperature and time. The autogenous shrinkage can be up to 100×10^{-6} of which 75% occurs within the first three months (JACKSON, 1990).

Drying shrinkage is caused by the withdrawal of water from concrete stored in unsaturated air. Since drying takes place at the surface of concrete, the magnitude of shrinkage varies considerably with the size and shape of the specimen being a function of the surface/volume ratio (ROSS, 1944). It has been found out that observed shrinkage decreases with an increase in the size of the specimen, but above

some value the size effect is no longer apparent (NEVILLE, 1977).

2.1 PRACTICAL IMPORTANCE OF SHRINKAGE

The importance of shrinkage in large massive structures, flatwork and pavements, precast structures, masonry construction etc is largely related to cracking. The importance of cracking and the minimum width at which a crack is considered significant depends on the conditions of exposure of the concrete. On the basis of a number of investigations, (KESLER, 1965), suggested the following permissible crack widths:-

Interior members	0.30mm
Exterior members	0.25mm
Exterior members exposed to particularly aggressive environment	0.15mm

Minimising shrinkage will help in minimising the cracks which are unwanted in the structures by the designer and the client.

3. OBJECTIVES AND SCOPE OF STUDY

The objectives of this research include the following:

* to design and produce concrete specimens using locally available materials
* to measure the shrinkage of the concrete specimens produced over a period of time.
* to monitor the effects of the size of aggregate, degree of workability, admixture and method of curing on the shinkage of concrete and come up with recommendations on how shrinkage of concrete could be kept at minimum. To provide an adequate scope of study, the following were employed:
* one type of locally available fine aggregate
* two different maximum sizes of locally available coarse aggregate (20mm and 40mm)
* one grade of concrete (20)
* low and high workability mixes
* ordinary portland cement
* laterite passing through 300mm sieve as admixture and
* three different methods of curing (dry, water and moist cloth)

4. EXPERIMENTAL DISCUSSIONS

The experiments conducted include:

* the sieve analysis of aggregates to determine their grading
* design of concrete mixes
* the slump test to determine the degree of workability of concrete
* the compressive strength test to determine the grade of concrete and
* measurement of shrinkage.

4.1 SIEVE ANALYSIS OF AGGREGATES

Sieve analysis were conducted to determine the gradings of the fine and coarse aggregates used. The results of the sieve analysis are presented in Tables 1A, 1B and 1C while the grading curves are shown in figures 1a and 1b.

From the grading curves it could be seen that the fine aggregate falls within the limit of B.S 882 zone 1, this implies that it is well graded and suitable for use in concrete. It is however to be noted that zone 1 is the coarsest possible grading for fine aggregate. In the case of coarse aggregates, it could be seen that the maximum size 20mm type falls within the limits of BS 882 while the maximum size 40mm type does not completely fall within the limits. This shows that the maximum size 20mm aggregate type is well graded and suitable for use in concrete while the maximum size 40mm aggregate type used is not well graded.

4.2 DESIGN OF CONCRETE MIXES:

Trial mixes were first designed to enhance the achievement of the required grade of concrete at the specified degrees of workability. The following information available in literature (Highes B.P. 1960, 1968, 1971) were helpful in designing the mixes namely: minimum cement content for durability for concrete with a specified maximum size of aggregate, relationship between aggregate cement ratio and compressive strength, water content per cubic metre of concrete mix with specified max sizes of aggregate and degree of workability and coarse - fine aggregate ratio.

The mix proportions were based on one cubic metre of concrete per batch. The weight per cubic metre (kg/m^3) of each material was estimated employing the understanding that:

$$\frac{A}{S.G.A} + \frac{C}{S.G.C} + W = 1000$$

were;

A	-	weight of Aggregate (Kg)
C	-	weight of cement (Kg)
W	-	weight of water (Kg)
S.G.A	-	specified gravity of aggregate
S.G.C	-	specified gravity of cement

The trial mixes were then formed into moulds, compacted, stripped, cured and tested. The results of the compressive strength tests of the trial mixes were used

as a basis for designing the actual mixes. Table 2 gives the results of mix design. For concrete with admixture, 5% by weight of laterite passing through 300 m sieve was added

4.3 SLUMP TEST:

Slump test were carried out to determine the degree of workability of fresh concrete mixes. A 300mm high concrete cone, prepared under standard conditions (BS 1881; part 102) is allowed to subside and the slump or reduction in height of the cone is taken to be a measure of workability.

4.4 COMPRESSIVE STRENGTH TEST

After forming, compacting and stripping the moulds, the concrete specimens were taken to the various curing stands - (water, moist cloth, dry). On the 28th day the specimens were taken from the curing stands and immediately crushed by loading at a constant rate of stress increase of between 12 and 24 NMM^{-2} min^{-1} as described in BS 1881: Part 116. The compressive strength of each specimen is given by:

$$\frac{\text{Crushing load}}{\text{Area of specimen.}} \quad Nmm^{-2}$$

150mm cube specimens were used for determining the compressive strength.

4.5 MEASUREMENT OF SHRINKAGE

Shrinkage of concrete specimens were measured as specified in B.S 1881; 1970. The first reading was taken for each specimen as soon as the concrete was set using a four-inch (100mm) gauge extensometer. Subsequent readings were taken after 1 day, 2 days,.... 7 days, 14 days, 21 days, 28 days and 42 days. The differences between the first reading and the subsequent ones give the values of shrinkage or swelling as the case may be. Shrinkage was measured in terms of strain by multiplying the readings by the gauge factor.

5. DISCUSSION OF RESULTS

Figures 2a, 2b and 2c show the distributions of shrinkage with time for the cases covered by the scope of this study. From figure 2a, it could be seen that for the same grade of concrete and degree of workability, concrete specimens cured under dry conditions experienced the most pronounced shrinkage followed by those cured under moist cloth, while specimens cured under water experienced swelling rather than shrinkage. This is because moist curing delays the rate at which water evaporates from the concrete on drying while dry curing enhances the rate at which water evaporates from the concrete.

For concrete cured under dry conditions, having the same grade and maximum size of aggregate (figures 2a and 2c), high workability specimens experienced more shrinkage than low workability ones. This is because for a given strength, concrete of low workability contains more aggregate than a mix of high workability made with aggregate of the same size and as a consequence the former mix exhibits lower shirnkage. However concrete cured under water or moist cloth did not follow this trend. This tends to suggest that the degree of workability enhances the shrinkage of concrete only when it is not cured in an environment with high relative humidity.

From figures 2b and 2c, it could be seen that for concrete with or without admixture, cured under dry conditions, having the same grade, specimens made with maximum size of aggregate 20mm experienced more shrinkage than concrete specimens made with maximum size of aggregagte 40mm. This is because larger aggregate permits the use of a leaner mix and hence results in lower shrinkage.

From figure 2c it could be seen that for grade 20 and maximum size of aggregate 20mm, concrete with admixture experienced more shrinkage than concrete without ladmixture, but the reverse is the case for concrete with maximum size of aggregate 40mm where specimens with admixture expreidfnced less shrinkage. This shows that admixtures could either enhance swelling or shrinkage depending upon its type and the constituent materials of the concrete most especially the aggregate size. In all the cases considered shrinkage jincreased with time with the most noticeable increase occuring at the early ages of the concrete.

6. CONCLUSIONS AND RECOMMENDATIONS:

6.1 CONCLUSIONS

For the cases covered by the scope of study:

* Shrinkage of concrete increased with time with the most noticeable increases occuring at the early ages.
* Concrete cured in an environment with higher relative humidity experienced less shrinkage than those cured in an environment with lower relative humidity.
* Shrinkage of concrete decreased as the maximum size of aggregate used increased.
* The higher the degree of workability of concrete the more its susceptibility to shrinkage especially for concrete cured under dry conditions. For concrete cured in an environment with high relative humidity, degree of workability had no effect on the extent of shrinkage.

* Admixture either enhanced swelling or shrinkage depending upon the constituent materials of concrete especially the size of aggregate used.

6.2 RECOMMENDATIONS

For shrinkage of concrete to be kept at minimum,

* In situ concrete should be kept wet at early ages to provide at least a type of curing similar to that of moist cloth. Completely dry curing which enhances shrinkage (and subsequently cracking) should be avoided.
* The use of high slump (High workability) mixes should be avoided.
* Well graded aggregate of largest practical size should be used.
* Admixture should be used so long as it is properly designed to enhance swelling, does not have adverse effect on the strength and produces no cracking tendency in concrete.

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TABLE 1A: SIEVE ANALYSIS OF FINE AGGREGATES:

Sieve Size	Weight Retained (g)	% Retained	% Passing
4.76mm	50	5.0	95.0
2.40mm	98	9.8	85.2
1.20mm	145	14.5	70.7
600mm	370	37	33.7
300mm	262	26.2	7.5
150mm	61	6.1	1.4
75mm	15	1.5	0.0
Receiver	20	2.0	0.0

TABLE 1B: SIEVE ANALYSIS OF COARSE AGGREGATE (MAXIMUM) SIZE 40MM)

Sieve Size mm	Weight Retained (g)	% Retained	% Passing
38.1	0	0	100
19.05	283	9.4	90.6
9.52	2647	88.2	2.3
4.76	53	1.8	0.6
Receiver	2.7	0.1	0.0

TABLE 1C: SIEVE ANALYSIS OF COARSE AGGREGATE (MAXIMUM SIZE 20mm)

Sieve Size (mm)	Weight Retained (g)	% Retained	% Passing
19.05	190	6.3	93.7
9.52	1700	56.7	37.0
4.76	850	28.3	8.7
Receiver	173	5.8	0.0

TABLE 2: RESULTS OF CONCRETE MIX DESIGNS:

S/No.	Concrete Grade	Max Size of agg (mm)	Degree of Workability	$\frac{W}{C}$	$\frac{A}{C}$	W Kg/m^3	C Kg/m^3	FA Kg/m^3	CA Kg/m^3
1.	20	20	High	0.7	6.1	211	301	612	1224
2.	20	20	Low	0.6	6.3	180	300	630	1260
3.	20	40	High	0.75	7.0	203	270	655	1232
4.	20	40	Low	0.7	0.8	207	260	700	1317

FA = Fine Aggregate

CA = Coarse Aggregate

$\frac{W}{C}$ = Water - Cement ratio

$\frac{A}{C}$ = Aggregate - Cement Ratio.

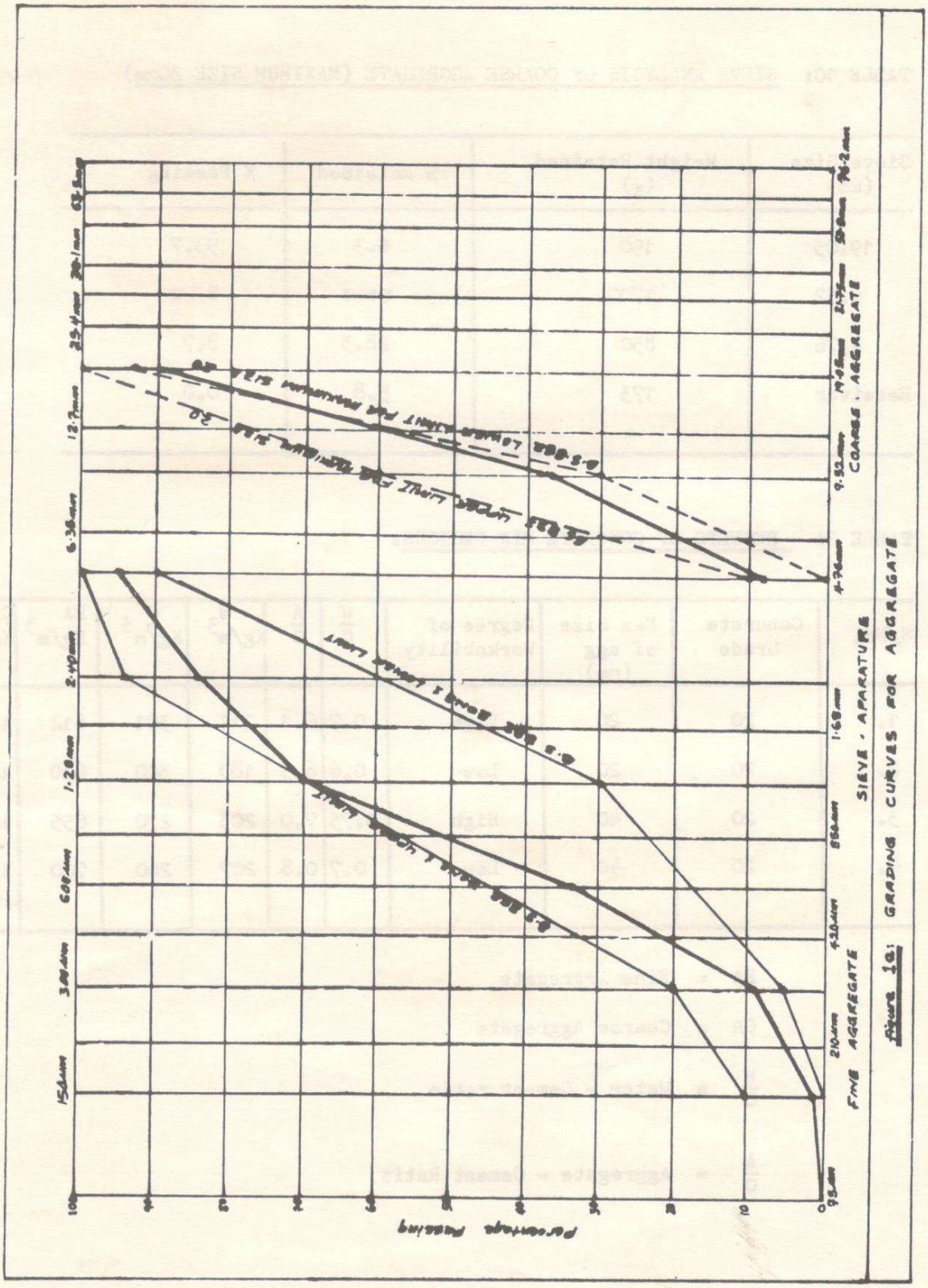


Figure 10: GRADING CURVES FOR AGGREGATE

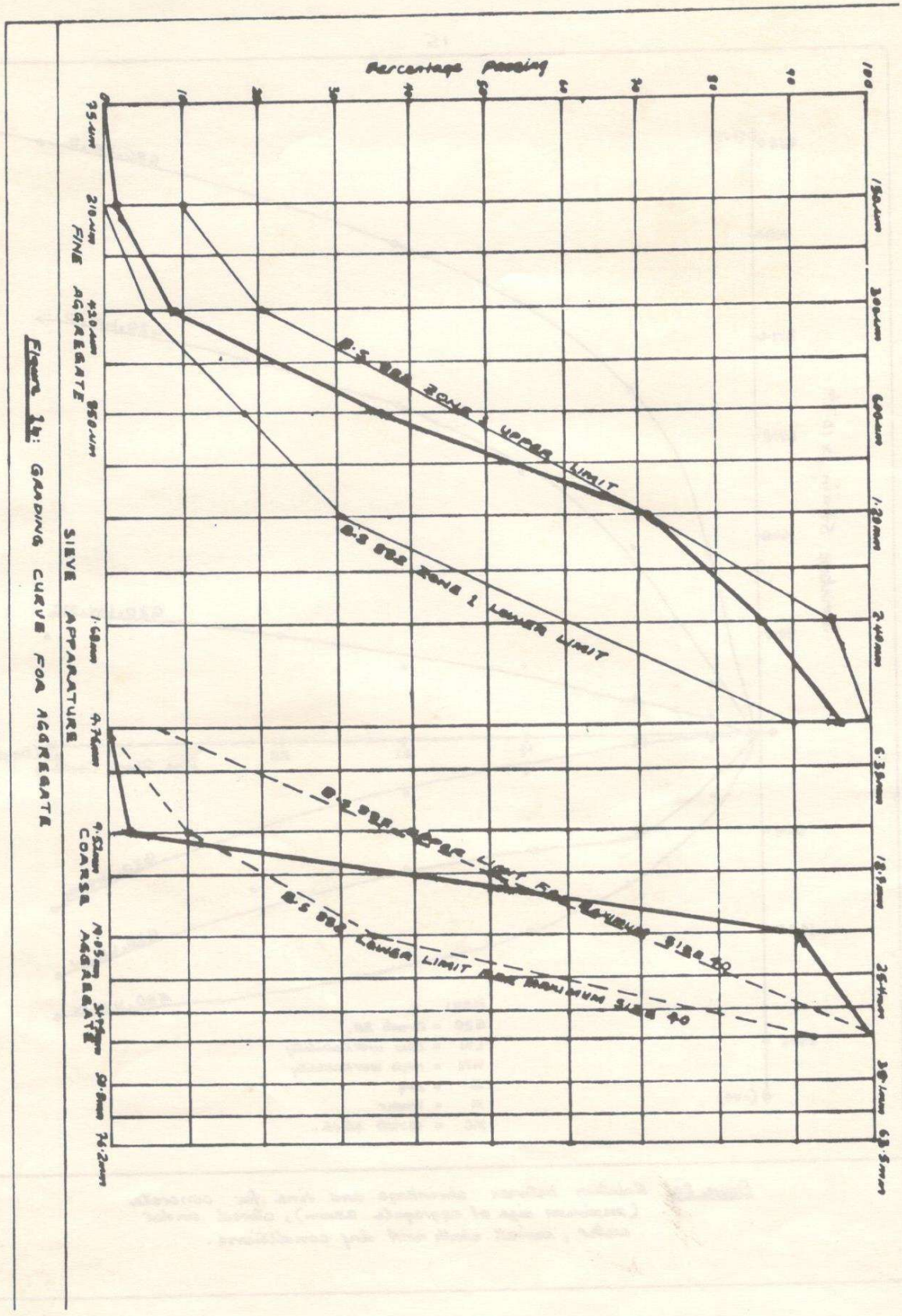


Figure 1b: GRADING CURVE FOR AGGREGATE

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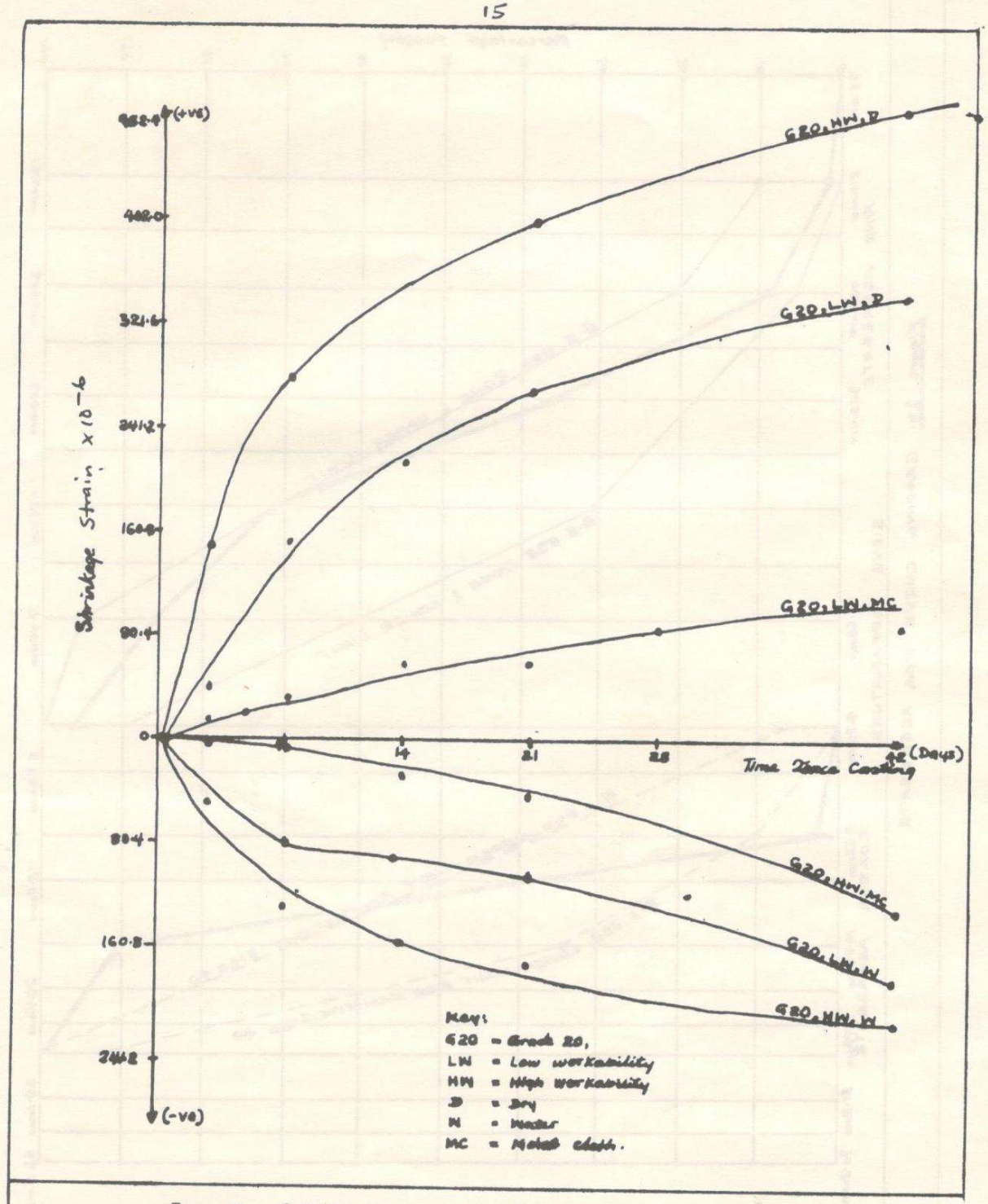


Figure 2a: Relation between shrinkage and time for concrete (maximum size of aggregate 20mm), stored under water, moist cloth and dry conditions.

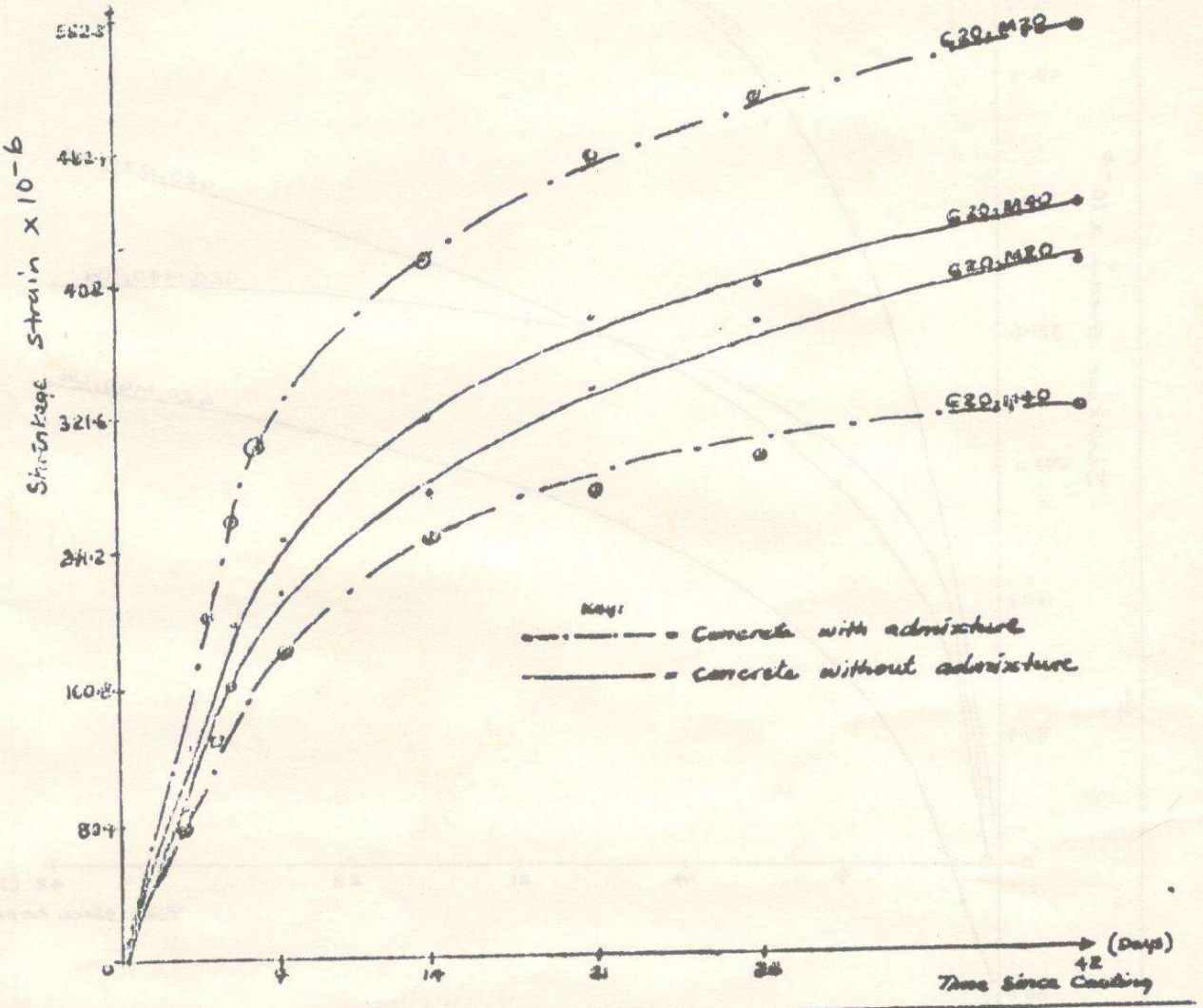


Figure 2b: Relation between average values of shrinkage and time for concrete specimens (with and without admixture), cured in dry conditions.

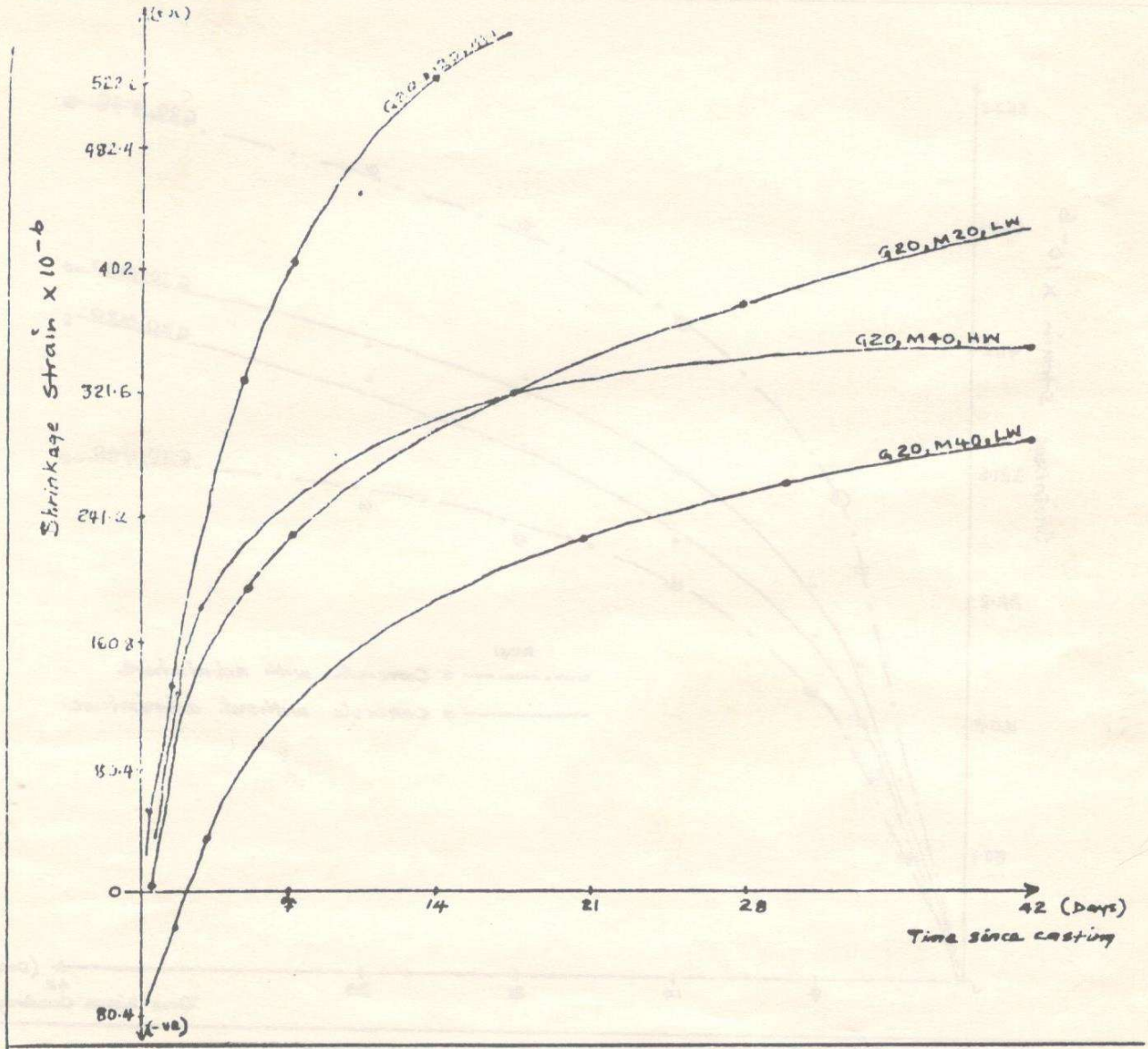


Figure 2c: Relation between shrinkage and time for concrete (with admixture), stored in dry conditions.

M 20 = maximum size of aggregate 20 mm
M 40 = maximum size of aggregate 40 mm