Strength development of plain concrete compared to concrete with a non-chloride accelerating admixture

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Abstract

Purpose – The purpose of this paper is to show how the investigation into early strength gain of concrete will allow the contractor to speed up the construction process using *in situ* concrete, which will affect subsequent time and cost savings. If a medium dose of accelerator was found to be effective, the cost/benefit would be substantial as well as being low risk with regard to additive additions in concrete.

Design/methodology/approach – Comparative examination of plain concrete, and concrete with a non-chloride accelerator additive was carried out, using the compressive strength to establish strength gain at various time intervals between one and 28 days. The additive dose was less than half of the maximum recommended to avoid the strength loss problems associated with the use of accelerating admixtures due to possible overheating.

Findings – The findings showed a significant increase in strength using an accelerating admixture in the early life of the concrete, which may allow a contactor to strike the formwork earlier, due to the use of an admixture, thus speeding up the construction process to produce time/cost savings.

Originality/value – The research will assist the designer, contractor and health and safety co-ordinator to strike formwork at the earliest date with greater certainty and therefore reduced risk. By using an accelerator, rather than increasing the cement content to achieve early life strength, this paper displays another way to produce sustainable buildings with a lower carbon footprint. Early life strength provides better freeze/thaw protection and a greater resistance to impact damage and therefore a potential higher quality with lower defects.

Keywords Accelerators (materials), Concretes

Paper type Research paper

Introduction

Concrete when used in construction has the inherent problem of curing to sufficient strength before formwork can be removed, thus in many cases slowing the manufacturing process. The construction industry is constantly developing new ways to speed up the process of constructing structures, whether it is with the use of *in situ* or pre-cast concrete. As Harrison (1995, p. 10) commented:

> The wider appreciation of time – related costs has resulted in commercial pressures to build quicker. An important facet of rapid construction is an understanding of the factors governing formwork striking times (and thereby the ability to minimize them without prejudicing safety).

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As a construction material, concrete has both beneficial properties and limitations, as its usefulness depends largely on the application for which it is required. As Neville (1990) points out "good concrete" needs to satisfy the performance requirements of the job or application it is used for. "Concrete floors require a mixture which is easy to place, does not bleed, has predictable setting and finish" (Concrete Society, 2002, p. 17). It is to fulfil these requirements that, when pouring *in situ* concrete floors, a structural engineer may specify the use of an admixture such as a water reducer, plasticizer, superplasticizer or retarder to achieve a more usable concrete mix. It is important for structural floors to offer high standards in terms of performance and durability. The Concrete Society (1998) state most concrete floors are satisfactory, however inadequacies in construction – particularly in the areas of finishing and curing – often lead to the need for remedial work at a later date. As lack of sufficient curing poses such a potential threat to the quality of the finished floor, anything that has the potential to significantly affect the curing process needs to be seriously considered as an aid to faster and high quality construction.

The use of non-chloride accelerating admixture to reduce formwork striking duration

> When planning the sequence of construction, it is necessary to estimate the formwork striking times. Reliable estimates of striking times can have a significant impact on time and costs (Harrison, 1995).

Harrison goes on to suggest ways of reducing striking times either through the use of cement with a rapid strength development, selecting a concrete of higher characteristic strength than required (however this would have adverse effects on workability, cost and heat production during curing) or by using an accelerating admixture.

Using accelerating admixtures (non-chloride accelerating admixture using Calcium Nitrate as the accelerator) can, as claimed by its manufacturer, "accelerate cement hydration, resulting in shortened setting times and increasing early compressive strengths" (Grace Construction Products, 1996). However this does not necessarily mean that using such a product will allow for the formwork to be removed sooner in all cases as many variables influence the strength development of concrete. The Concrete Society's (1998) guidance on specification, mix design and production of concrete for industrial floors notes that many experienced flooring contractors resist temptation to use admixtures. This is because during dry batch concrete mixing it can be difficult to fully disperse the admixture effectively, resulting in the inability to achieve a "fully consistent concrete" which is of "paramount importance in the very large pours which characterise today's fast-track floor construction process" (Concrete Society, 1998). The use of accelerating admixtures can be of use when concreting in cold weather as strength gain is faster than plain concrete thus providing early life strength and freeze/thaw resistance. The chemical reaction between the Portland cement and water is accelerated because the admixture speeds up the formation of gel (the binder that bonds concrete aggregates together) which therefore shortens the setting time of the concrete.

There is a drawback however to using accelerating admixtures, as Grace Construction Products (1996) note that, "in common with most concrete accelerators, the inclusion of Daraset 580 C may reduce the ultimate compressive strength of concrete". They also suggest that before the product is used, mix trials should be carried out to establish the extent to which the compressive strength is weakened.

Test method

Two types of concrete were manufactured, one plain and the other with a non-chloride accelerating admixture (Calcium Nitrate to EN 934 – 2) used at 1,500 ml/100 Kg of CEM 1 as shown in Figure 1.

The control cubes were tested for compressive strength to evaluate comparative consistency between the batches. Care was taken to dilute the admixture with the mixing water prior to the batching to ensure even dispersion of the accelerator. Cube temperature was monitored using a centrally embedded thermocouple to observe whether or not the use of an accelerator caused additional heat gain when compared to plain concrete. No statistically significant temperature rise was observed between the two concrete types as shown in Figure 2.

The cubes were removed from the moulds after 24 hours and left to "air" cure within the laboratory, (the laboratory had an ambient temperature of 20°C). They were then tested at prescribed intervals of one to 28 days. The samples were tested for compressive strength in accordance with BS EN 12390-3:2001 (Code of Practice, 2002) using an applied force of 0.25 N/mm^2 per second.

Control cubes

In construction, differences occur in properties of materials. Building and Civil Engineering construction is particularly concerned with the deviations of Compressive strength of concrete. "A standard deviation . . . is seldom less than 2.5 and no more than

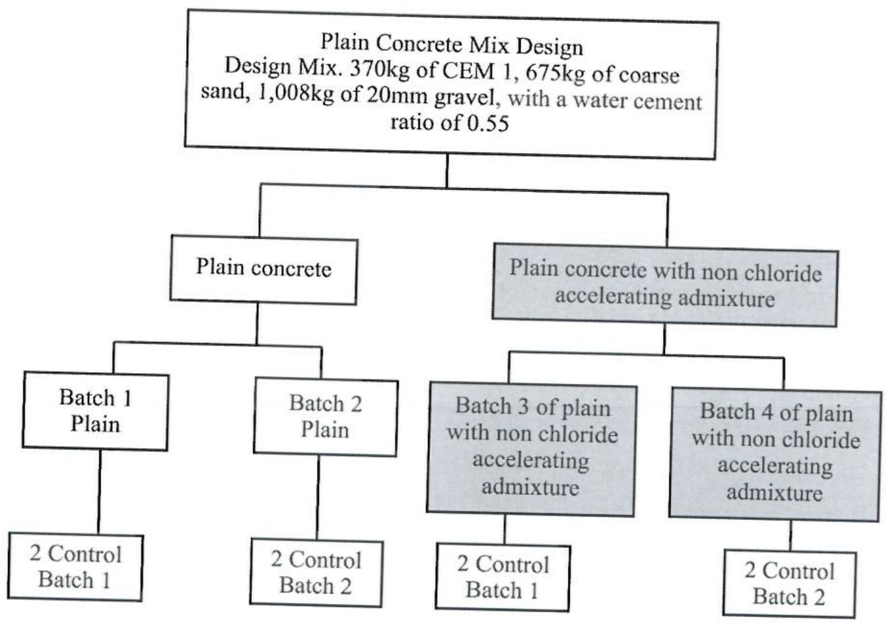

Figure 1.
Concrete batching plan

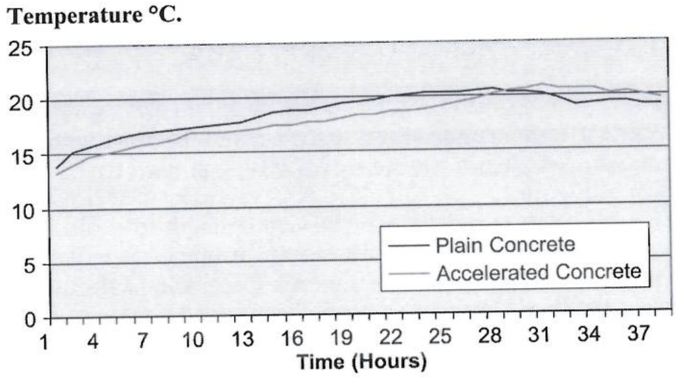

Figure 2.
Thermocouple temperature test results

8.5N/mm^2."(Building Research Establishment, 1987) These parameters apply to concrete over 20N/mm^2.

Two control samples were taken from each batch to correlate the results between all four batches (two plain and two accelerator). The control samples were tested after 28 days to test each batch for strength and quality. The compressive strength results all achieved values between 35-41 N/mm^2. Mean strength values were 37.5 for plain concrete and 39.75 N/mm^2 for concrete with an accelerator addition. The control samples were within acceptable limits for concrete production.

Compressive strength results

The non-chloride accelerating admixture batches did not have the same strength at each point, after seven days of curing the second batch of accelerated concrete, (4) was almost 10N/mm^2 greater strength than the same batch design (3). However as Table I shows, the rate at which the two batches gain in strength is very similar, as we can see by the way the margin between the two remains similar throughout the 28 days of curing.

Conclusion

The research has shown that using a non chloride accelerating admixture does increase the early strength development of concrete (Figures 3 and 4); the compressive strength

Days	Compressive strength results N/mm^2 Plain Mix 1	Plain Mix 2	Accelerator 3	Accelerator 4
1	2.31	4.11	7.51	11.68
2	5.83	9.89	17.39	18.89
3	15.20	13.34	20.32	24.69
4	13.09	14.39	26.40	24.88
7	14.40	27.35	32.63	41.90
10	19.58	25.32	35.35	44.12
14	20.80	28.11	37.09	47.39
20	36.34	40.29	41.42	49.87
28	36.04	37.55	42.41	47.31

Note: Batches shown as 1, 2, 3 and 4

Table I.
Compressive strength results table

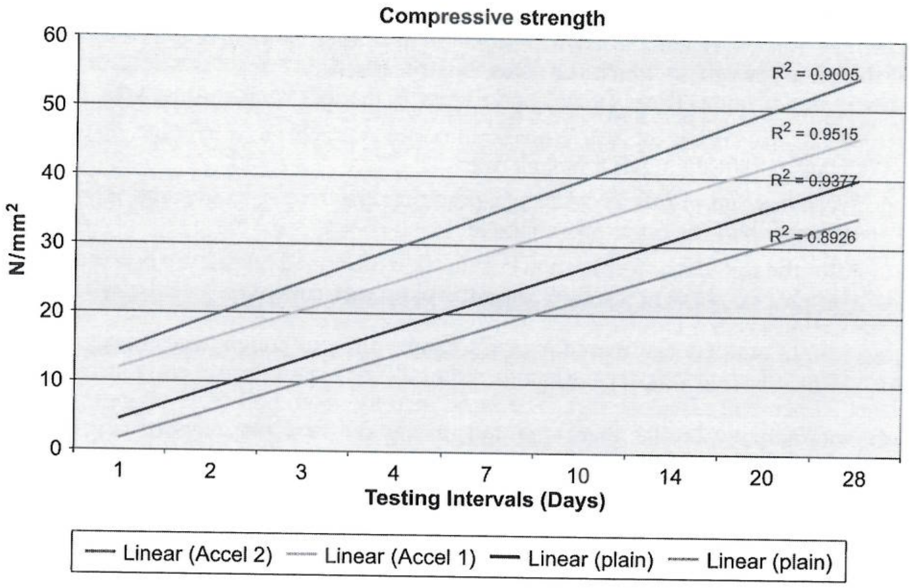

Figure 3.
Compressive strength results
(Accel = accelerator additive)

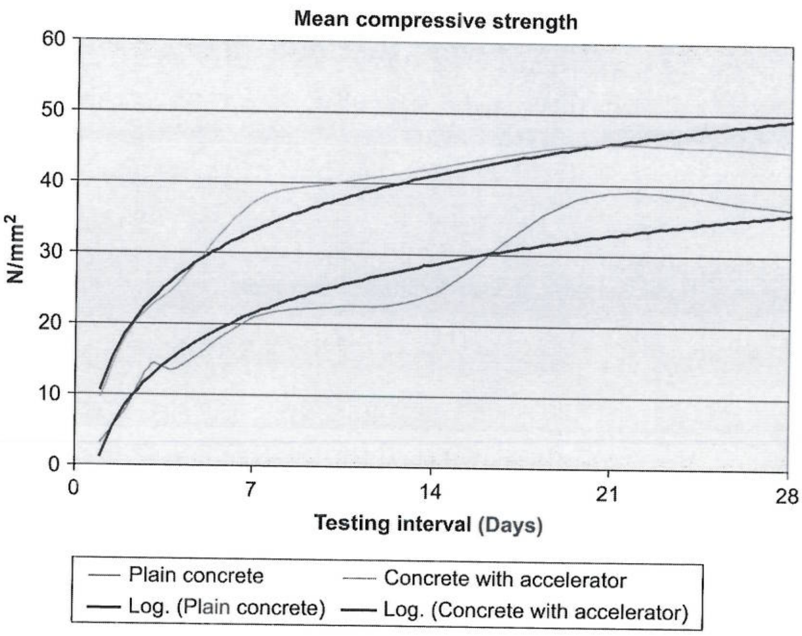

Figure 4.
Cube strength gain
(0 to 28 days)

was higher for the accelerated mixture than a plain mix of concrete for equal curing times. The admixture had clearly increased the hydration process of the cement paste and therefore the rate at which the concrete strengthens.

Using mean values from Table I and Figure 4, the following results were shown:

- One day of curing the accelerated admixture concrete is, on average, 66 per cent stronger than the plain mix concrete.
- Seven days curing the accelerated admixture concrete is, on average, 29 per cent stronger than the plain mix concrete.
- After the full 28 days of normal curing the accelerated admixture concrete is, on average, 7.6 per cent stronger than the plain mix concrete.

These results support the manufacturer's claims that, although accelerators do not have a large effect on long-term concrete strength, they can improve early strength by at least 25 per cent after one day. The rapid increase in compressive strength in this study was actually higher than expected during the first few days of curing. The results show that early striking of formwork is a possibility using a non-chloride accelerating admixture and higher early strength will help protect the concrete from impact and early life freeze/thaw damage.

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