IS COURSE CORRECTION NEEDED FOR DIRECTION OF RESEARCH IN CONCRETE

Sandeep Holey (Head- Technical & QA)
(Email: Sandeep@ultratechcement.lk)
Ananda Silva (Snr. Manager- Technical)
(Email: ananda@ultratechcement.lk)
H.T.P. Perera (Senior Chemist)
(Email: laboratory@ultratechcement.lk)
W.G.M.A. Wijayakulatilaka (Senior Chemist)
(Email: laboratory@ultratechcement.lk)

Abstract: This paper is an endeavour to highlight importance of realizing potential of research in "value addition" or "making" process of concrete. Authors, based upon their experience as link of cement manufacturing and construction industry, presented information on data generated in past five years in Sri Lanka for various purposes/studies as well as observations and interaction with concerned from the spectrum of Industry.

The paper, while questioning the overemphasis given to "material" part of concrete, shares the learning, which could benefit the Industry, in ensuring consistent superior quality and economy of concrete and suggest the areas for future research.

Keywords: Physical and chemical parameters of cement, Concrete strengths and strength deviation, Compatibility,

1. Introduction

The idea of this paper got triggered from a discussion on cost of material versus value addition to focus upon the area, which has got tremendous potential to further the work of research.

The concrete cost is mainly the raw material cost (about 70-75% in Sri Lanka) and substantially higher than cost of value addition of process (workmanship) involved in its making, placing etc in a structural element. Although it is difficult to get a universal idea of costing due to difference in material and labour cost across countries but a preliminary work on same confirm the major part of costing in concrete is for material.

The value chain in construction industry can be depicted as:

Cement & aggregates ------Value addition-----Concrete---------- Value addition---Structural Members-- Value Addition -----Buildings/structures

Advances in the fields of material (for example cement) due to technological developments and in the fields of analysis & design have been substantial but somewhere the advances in the area of value addition in converting cement/aggregates to concrete is not able to match with other areas as mentioned above. Although the introduction of batching plants for ready mix concrete has some positive effect but still it has good potential to work upon further.

With this background, objectives of the exploratory research were laid down as following:

a) Analyse the available data in the field of cement and concrete to establish the need of further research in the area of value addition in process of making concrete.

b) Identify the areas, where research can help in achieving either the purpose of reducing cost or improving quality control and reliability?

c) Share the learning from the process, which can be readily applied in achieving the purpose of economy and quality in the field of construction.

2. Experimental works and analysis of data;

a) Series of trials of making concrete with a particular cement and co-relation of cement quality with that of concrete:

As cement is a raw material for concrete, it is tested on a regular basis in UltraTech's in house laboratory for its physical and chemical parameters and also by testing concrete made with this cement.

For the ease of illustration, co-relation of strength of cement and concrete for 28 days strength is shown in figure 1 and that of % age gain of strength of 7 days over 28 days strength is shown in figure 2.

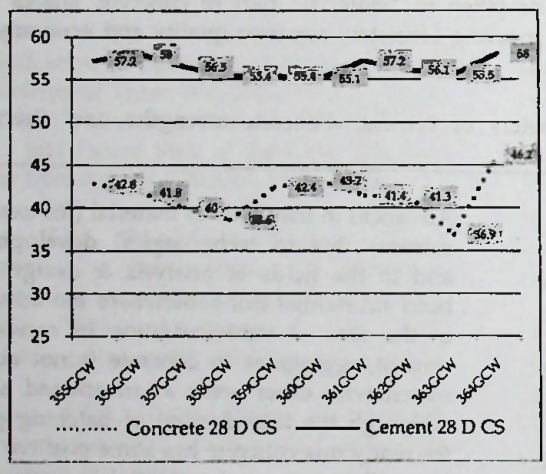

Figure-1

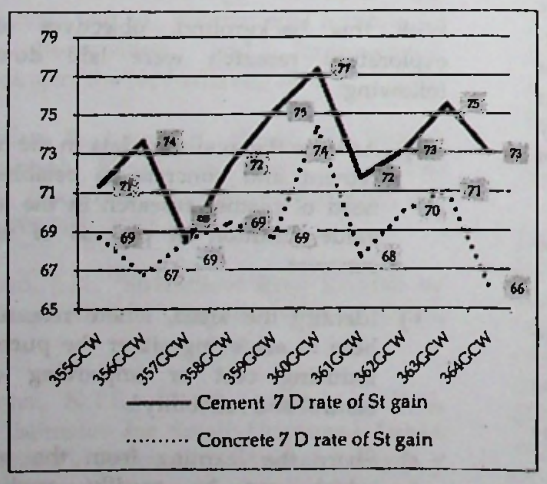

Figure-2

As can be observed from figure 1 and 2, it is difficult to co-relate strengths of conncrete with that of cement. Although the co-relation of both strengths can statcistically said to be fair but from practical point of view, constrcutors, can not be assured of concrete strength based upon cement srength alone. There can not be any quesiton on overall trend of corelating cement and concrete strength but it certainly is for a subtle point of unpredictability of concrete, which forces a designer or constructors to increase cement content to accomodate higher variationn in concrete strengths.

b) Inter laboratory results variation:

Table-2

Parameters	UltraTech Sri Lanka	UltraTech India	Independent lab 1	Independent lab 2	SLS 107 specs
Fness m²/kg	309	300	254	312	>225
IST min	150	155	150	160	>60
CS2D MPa	26.8	23	26.3	29	>10
CS28D MPa	60	58	56.3	62.5	42.5-62.5
Snd mm	1	1	1	0.32	<10
LOI %	1.19	1.45	1.3	1.26	<4
IR%	0.78	1.1	1.4	1.39	<1.5

As seen in table 2, although the sample is well surpassing the requirement of SLS specifications in all laboratories but there is substantial difference on few parameters among various laboratories for the same sample tested with same specification procedure and all are reputed labs with good controlled environment conditions.

c) Consistency:

Use of superior strength (and optimum physical and chemical parameters) of cement consistently from one source can results in higher characteristic strength of cement and hence quality and economy in concrete.

As shown in figure 3, monitoring of quality of samples of cement supplied from same source at regular interval of time, resulted in higher characteristic strength of the cement as following:

Cement ck Strength = mean strength - 1.65 * standard deviation = 56.75 MPa

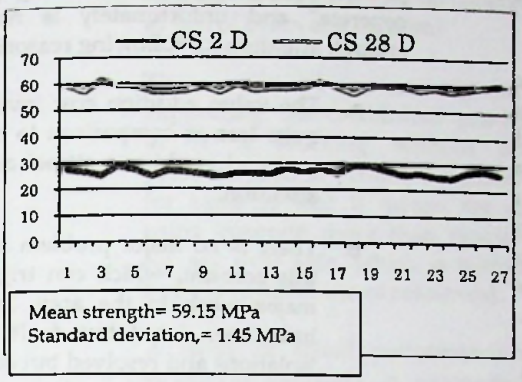

Figure-3

Whereas, in similar monitoring of quality of different cement's supplies from various sources, the characteristics strength of cement is found to be quite low i.e. 41.72 MPa as shown and calculated from Figure 4. This is a common situation in import dependent markets, wherein, a domestic customer can end up using various cements during construction period of his project and might compromise in quality and economy of concrete.

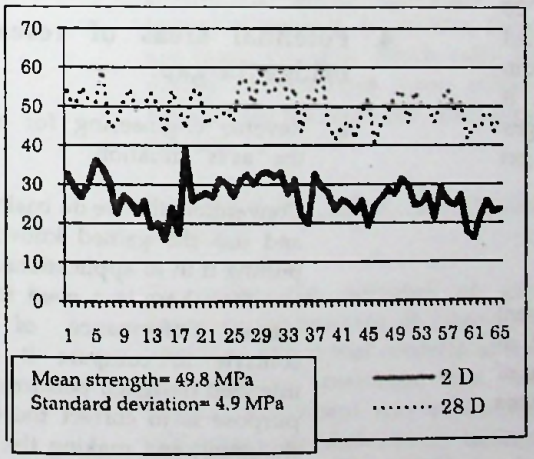

Figure-4

d) Compatibility with admixtures:

Occasionally in concrete the particular combination of cement and admixture(s) does not perform in the expected manner and can typically results in change in flow behaviour or setting time. Study conducted on a G 30 concrete indicated following results:

Table-3 Concrete with same cement with different admixture

Ad-mixture	Dosage	Slump Retention				Concrete Strength		
	l/m3	Init	1 hrs	2 hrs	3 hrs	1 D	7 D	28 D
Control led	-	45	-	-	-	15	35	48.5
R1	1.65	0	200	170	150	9.59	41.7	55.39
P1	4.2							
Control led	-	45	-	-	-	15	35	48.5
R2	0.518							
		0	195	180	150	0	36	50
P2	3.312							
Control led	-	45	-	-	-	15	35	48.5
R3	0.414	0	195	180	135	2.2	33.7	46.6
P3	2.48					25 hrs		

As evident from table 3, same cement can give different results with different admixture and it is possible to get best results with a particular type and dosage of admixture.

As evident from table 4, even a small variation in admixture dosage can have substantial effect on slump retention and compressive strength of concrete.

Table-4: Small variation in dosage of same admixture

Ad-mixture	Dosage	Slump Retention				Concrete Strength		
	l/m3	Slump (0 hrs)	1 hrs	2 hrs	3 hrs	1 day	7 day	28 day
R3	0.414	0	195	180	135	2.2	33.7	46.6
P3	2.48					25 hrs		
R3	0.331	0	200	175	165	0.2	25.6	37.2
P3	2.898							

Table-5: Even delay of adding same dosage of same admixture can give variation

Ad-mixture	Dosage	Slump Retention				Concrete Strength		
	l/m3	Init	1 hrs	2 hrs	3 hrs	1 D	7 D	28 D
Along with water								
R1	1.6	210	190	165	90	10.21	37.92	49.95
P1	3.2							
5 minutes delay								
R1	1.6	0	210	185	160	3.45	32.9	47.35
P1	3.2					30 hrs		

As evident in table 5, even delaying the addition of admixture changes the slump retention substantially.

The above results support the available scientific evidences and drive the point that compatibility of cement and admixture needs to be addressed in a sensitive and systematic manner. It is also a proven fact that for any cement, a particular combination and proportion of admixture exists and it is very much possible to get desired results on slump and it's retention without compromising on physical attributes of concrete.

e) Concrete mix design for various grades

Table-6

Grades with single cement				A/C ration	Cement consum ption	W/C
Grade	1 day	7 day	28 day			
20	9.5	20.3	32.3	6.1	320	0.5
25	10	24	34	5.2	360	0.5
30	13.5	30.4	37	4.6	392	0.47
35	15.6	37	49	4.0	450	0.38
40	13.7	31	52.5	3.6	475	0.41

In table 6, first observation is from G 20 concrete as it seems to be an overdesigned mix and second observation is quantum increase in strength at G 35 onwards. It supports the fact that concrete mix designs can be (rather should be) optimized to get material and especially cement savings.

3. Discussion:

Data evaluation, as detailed above, present adequate evidences to support the fact of variation of quality of concrete on account of workmanship and environmental conditions apart from quality of ingredients.

Another important observation is that substantial improvement in key material like cement (strength of 55+ against minimum requirement of 42.5 N/mm2) is not ensuring the superior strength of concrete on a consistent basis.

It obviously raises a question of where the gap is and how we can make efforts in bridging it by initiating structured research work, which might lead to innovation for "ensuring superior quality of concrete with consistency and hence economy".

Authors feel that major gap is in the value addition process i.e. the "making part of concrete" and unfortunately is not paid enough attention for following reasons;

a. The value addition cost involved is quite less as comparison to material cost and could not attract adequate attention.

b. There is no major problem faced on this account, which can trigger out major work in the area. Problems have been faced but dealt with in isolations and resolved but could not present any universal or standard solution.

c. Commercial benefits resulting out of consistent superior quality of concrete are not yet adequately recognized, which can give enough motivation for research in this area. For example, data presented in point no 2, d) i.e. making use of consistent quality of cement itself present scope of 2-4% saving in cement consumption.

4. Potential areas of research to bridge the gap:

a. Reverse engineering for analysing the "as is" situation:

Conventionally, we do basic research and use the gained knowledge by putting it in to applications. Authors feel that there is a need to test the actual performance of existing concrete to compare it with it's intended designed performance. The purpose is to correct the course of designing and making the concrete, if analysis demands so.

To illustrate the point, let us take a basic example of designing, producing and placing a concrete mix say Grade 30 as per the structural designer's requirement and testing it through conventional cube tests. In this case, we are co-relating the cube strength with the strength of concrete used in structural members of various shapes (flat, long, wide etc), which are connected with each other at

joints, which is heavily reinforced. Is it appropriate to co-relate the strength of cube with actual concrete at join of beam and column?

There can be an argument supporting the established practice as it is working without any problem. Author's counter-argument for same is that it means we are using concrete more than required (or say over safe, which is nothing but uneconomic use of resources).

A study of actual performance of structural members in comparison with it's original design and intended execution shall give us an insight to optimize the concrete and hence economy. The scope of this study can range from physical parameters like strength and more importantly the wide open field of durability.

b. Testing parameters and methods;

We are still following the 28 days compressive strength as the basic criteria for design, execution and testing of concrete. In practice, there are many changes, which calls for review of this (and many others) testing parameters for following reasons:

Site simulated rather Site specific Testing's;

To avoid the potential of gap between performance of laboratory specimen and actual concrete at site in structural members, can we explore a different way of testing. Although non-destructive tastings (NDET) are already available but its usages are still not common due to expenses and expertise involved. Can there be a way in between concrete cube tastings and NDET or can NDET be further worked upon to make it more affordable and usable at site on regular basis.

Secondly, in place of "one for all" standard cube testing procedure for all shape and size of structural members, can we think of specific testing more relevant to particular members? To illustrate the point, let us take example of compressive strength as it is more relevant for vertical member like column. In place of it, flexural strength testing shall be more relevant for structural elements like beams. Although there is a good co-relation between both types of strength and it is specified also but at some places, it is not used in totality. (For example in case of cement testing as per BSEN specification, both types of strength is specified but it's adoption in SLS did not insists on flexural strength, which results in practical issue of breaking the prism in halves.)

Ordinary Portland cement of lower strength was the common type of cement in past with lower % age of tri calcium sulphate, which was the reason of slow strength development. Now most of the Ordinary Portland Cements, due to advancement in manufacturing technology, have higher % age of tri calcium sulphate, which results in faster strength development. Despite this known fact, why do we still follow 28 days strength criteria for testing and design especially when the actual practice of construction has already changed for early de-shuttering and faster concreting for next layer or level. Although there has been efforts for last 50 years to check the strength with accelerated tests like steam curing but nothing has replaced in practice till time.

Specific or tailored tastings in place of standard and universal testing's:

To illustrate the point, why do we need same criteria of 28 days compressive strength for fly ash or pozzolana based cements/concrete as we know well that secondary gelification process of pozzolana takes time? To know it's effect, why cannot we have a longer period say 56 or 84 days to establish the effect of secondary hydration.

c. Fundamental areas of concrete making;

As explained in earlier section of this paper, uniformity of concrete can lead to

substantial savings apart from improving quality. Unfortunately, there are not enough efforts to address the innovation required here and it could be in the field of:

- Moisture content in aggregates: This is one of the major reasons of variation in strength of concrete. Although there exists a manual method of moisture correction but it's implementation and effectivity remains an area of concern. Innovation in the field of production technology by automated moisture measurement and control can address the issue. Is it possible to work backward from measurement of moisture in dry mix of concrete already poured in drum and then to pour remaining water as per computerized online calculations with automatic online command. It seems too sophisticated for concrete but might lead to a revolutionary change in economy of concrete by ensuring its uniformity.
- Curing: Despite the best possible control systems, it is difficult to be ensured on site and hence present a good potential to research either on effectivity of existing methods or by innovating an all together different method or material(existing curing alternatives like compounds/membrane etc are still not the affordable replacement of water curing)
- Compatibility issue: As explained in section 2. d), the issue of compatibility between cement and admixtures, in spite of ongoing efforts, is not getting addressed to a workable solution. We do resolve the incompatibility cases in isolation but there is no standard, effective and affordable common practice to check batch to batch material variation and compatibility among them.

5. Conclusion:

Authors would like to conclude the paper in two parts i.e. learning from the tests undertaken and proposing the direction and scope of future research.

Tests carried out and data evaluation leads to following learning,

a. Although goodness of ingredient material do not necessarily lead to goodness of concrete but it can be ensured with reasonable confidence if proper attention is paid to know-how part i.e. workmanship and it's execution.

b. Cement, being the key ingredient of concrete, should be selected on the basis of superior strength, optimum chemical composition and consistency of these physical and chemical properties. Good manufacturer do check and ensure their products (cement) performance in application area like concrete and hence users should make use of know-how and services available from reputed and quality conscious manufacturers.

c. Engineers should base their decisions on comprehensive information for example testing reports for many samples from various laboratories in place of one and two isolated reports and more information collection from manufacturers on their raw materials and process.

d. It is possible to make a better quality concrete with economy with consistently superior quality of materials like cement if it is from single source.

While appreciating the ongoing research work in the concrete arena, authors would like to emphasize on directing more efforts towards analysing the performance of existing concrete, testing parameters & methods and fundamental changes in making of concrete.

Otherwise neglected, minor part of "value addition" is one of the major reasons of variability of concrete quality and hence authors propose the idea of greater testing, analysis and better directed research to incorporate "the predictability" in concrete quality and hence economy.

References:

Neville A (2003), Neville on Concrete

www.astm.org/COMMIT/C01C09_Research.doc

Laboratory records of UltraTech Cement Lanka (P) Ltd, Colombo