Cementitious Material Reduction

Introduction

The use of CNS (Colloidal Nano Silica) technologies, the integral admixture CNS and the post-set applied CNS have demonstrated superior strength gaining characteristics for Portland cement concrete mixes compared to water-submerged samples. Of recent interest is the potential opportunity to trim cementitious materials (Portland cement and associated supplementary cementitious materials) while still maintaining compressive strength characteristics through the use of the CNS technologies.

There are several desired outcomes from reducing cementitious content. First, cementitious paste is the portion of the concrete mix where shrinkage, both drying shrinkage and autogenous shrinkage, occurs. By reducing the total volume of paste, it is well accepted that shrinkage can be reduced. This is a positive outcome because shrinkage is the primary originator of concrete cracking. Cracking, in addition to being unsightly, can be a structural and durability concern. Second is a simple economic concern. Cement and associated supplementary cementitious materials are typically much more expensive than aggregates. By reducing total cementitious content of a given concrete mix through the use of CNS technologies, a net economic gain may be realized. Finally, there is an environmental concern. The production of Portland cement ranks second only to steel production in the generation of greenhouse gas emissions among all building materials. By reducing the amount of Portland cement in a concrete mix design the overall environmental impact of the construction project can be reduced.

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Analysis

Compressive strength is typically measured at twenty-eight (28) days. A significant track record of compressive strength performance of CNS-treated concrete has been assembled from testing at seventeen (17) different laboratories in nine (9) different countries. In each case, the compressive strength gains are expressed as a Percentage gain over a non-treated control. For the purposes of this analysis, these gains are averaged and reported below:

Table 1

Product	Average Compressive Strength Gain over Water Cured Control (%)
CNS Admixture	**8.7**
Spray Applied CNS	**21.8**
CNS Admixture and Spray Applied CNS	**24.0**

For production use, the increase factors above in table 1 would be generated from laboratory testing with production materials. For a given mix design, the original 28-day compressive strength may be expressed as a function of compressive strength unit/mass of cementitious material. For example, if a mix containing 400 kg/m3 (674 lbs/yd3) cementitious material produces 28-day compressive strength of 50 MPa (7250 psi), then the concrete mix can be said to have a cementitious efficiency value of .125 MPa/kg (10.76 psi/lb). By applying the percentage compressive strength gains in Table 1 to the mix design, we can increase the expected cementitious efficiencies. For example, if we want to look at each treatment case, we can derive the following estimated new cementitious contents to maintain the current levels of compressive strength:

Table 2

Condition	Cementitious Efficiency, MPa/kg (psi/lb)	Total Cementitious Content, kg (lb)	Projected Compressive Strength, MPa (psi)
Control	**.125 (10.76)**	**400 (674)**	**50 (7250)**
CNS Admixture	**.136 (11.70)**	**368 (620)**	**50 (7250)**
Spray Applied CNS	**.152 (13.11)**	**328 (553)**	**50 (7250)**
CNS Admixture and Spray Applied CNS	**.152 (13.11)**	**323 (543)**	**50 (7250)**

However, workability may be adversely affected by the change in cementitious content leading to more water demand, which in turn will lead to less cement efficiency. It is suggested that the mix design be examined carefully using methodology first put forth by Shilstone and widely adapted which uses workability and coarseness to approximate concrete mix placing and finishing characteristics. In many cases, this may lead to adjustment of the cementitious content somewhere between the minimum level shown in Table 2 and the original level. Local aggregate characteristics will largely dictate the impact of reduction of cementitious materials on workability.

If, for example, the above concrete mix contains three aggregates, a 25mm (1") maximum sized coarse aggregate (Coarse1, 42.1% of aggregate volume), a 9.5mm (3/8") maximum sized coarse aggregate (Coarse2, 15.9% of aggregate volume), and one concrete sand (42.1% of aggregate volume) with the sieve profiles in table 3 below, it will yield workability graph extremes as shown in figures 1a and 1b.

Table 3

Sieve Size	Percent Passing, Coarse 1	Percent Passing, Coarse 1	Percent Passing, Fine	Combined Percent Passing
25mm (1")	100	100	100	99.8
19mm (3/4”)	99.5	99.6	100	94.9
12.5mm (1/2")	88	57.2	100	75.5
9.5mm (3/8")	58	30.3	100	53.2
4.76mm (US 4)	15	1	98.9	42.1
2.38mm (US 8)	0.9	0	82.7	34.8
1.19 mm (US16)	0	0	55.9	23.5
0.595mm (US30)	0	0	37.3	15.7
0.297mm (US50)	0	0	17.2	7.2
0.149mm (US100)	0	0	6.1	2.6

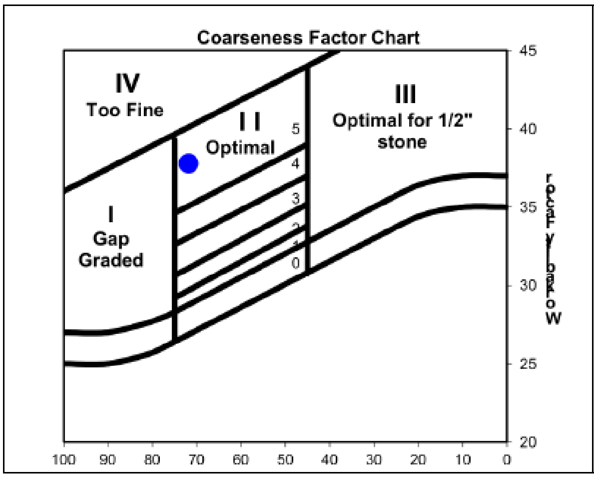

Fig 1a: Coarseness and Workability Chart for Original Untreated Mix design

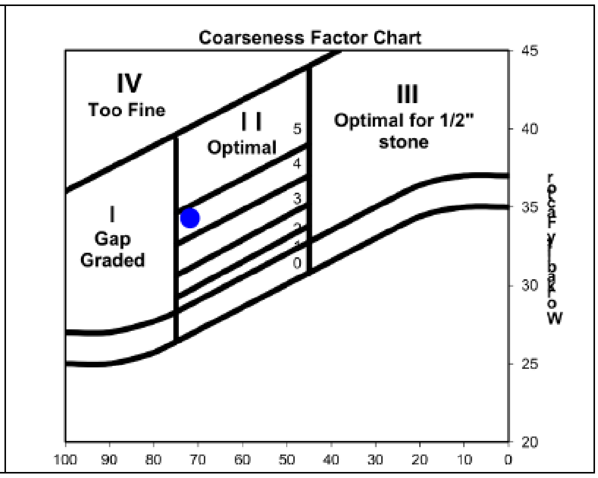

Fig 1b: Coarseness and Workability Chart for Mix Design with Reduced Cementitious Content

As can be seen above, the workability factor (y axis) above in figure 1a is approximately 38, with the workability factor being brought down to around 35 in figure 1b after cementitious content is reduced. This translates to a difference in fresh concrete behavior. Only testing with local materials to ensure proper workability and compressive strength will allow users to set their "true" level of needed cementitious materials. Adjustments to other admixtures (high range water reducers etc.) maybe required. It should be noted, however, that an intrinsic property of CNS is to improve workability, so the needed adjustments may be minimal.

Durability of the concrete will be improved in most cases with the use of CNS technologies, even if cementitious material content is reduced. Because CNS technologies reduce capillary void volume, they reduce the primary route for the damaging effects of water and contaminants. In addition, they reduce drying shrinkage, and thereby reduce cracking.

Conclusion
The use of CNS technologies can, when utilized according to the manufacturer's recommendations, reduce the amount of total cementitious content needed to achieve desired compressive strength. Workability may be affected by the reduction of cementitious materials content, so laboratory testing with the proposed materials for the target project must be performed.

Reduction of cementitious materials can generate the following desirable outcomes:

- Reduction of drying and autogenous shrinkage
- Reduction of cost of production
- Reduction of environmental impacts

In deep calculations can be requested per email to info@c5st.com