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A Reply to a Discussion by F. de Larrard and J. Marchand of the Paper "CEMENT-SATURATION AND ITS EFFECTS ON THE COMPRESSIVE STRENGTH AND STIFFNESS OF CONCRETE"*

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We thank Messrs de Larrard and Marchand for their interest in our paper and their stimulating comments. Our response to their comments is as follows:

In their first paragraph, they state that we (Addis and Alexander) in our paper say "the intrinsic strength does no longer increase with an increment of the cement/water ratio." This is incorect. Our paper clearly states and demonstrates, that strength does increase with an increment of C/W, but that rate of increase in strength tends to decrease with increasing C/W.

Also, in their first paragraph, they do on to state that we say "The additonal increase of strength for higher C/W is attributed to an enhancement of the paste aggregate interface." This statement contradicts the one discussed above. It is also incorrect. We say in our paper that increases in strength, with increments of C.W at values higher than "cement-saturation," are due to unhydrated clinker behaving like small aggregate particles which have good bond with surrounding gel.

Messrs de Larrard and Marchand claim that their results of work done on cement pastes, contradict our theory. We submit that they do not. Firstly, the data in their Figure 1 is too sparse to show anything other than a tendency for strength to increase with increasing C/W. Secondly, results obtained on paste specimens cannot necessarily be extrapolated into the behaviour of concrete: paste does not have the mixing action of aggregate particles; neither does it have aggregate-paste interfaces in the hardened state.

They state that their Figure 1 shows no signs of cement saturation. This is not surprising. As mentioned above, the data in Figure 1 are too few to be significant. Also, ploints plotted on axes of strength and C/W do not clearly show cement saturation; cement-efficiency versus C/W is far better.

We agree that their Figure 2 indicates a relationship comparable with that shown in our Figure 6. But one should note differences in the way in which data was generated. They kept paste volume constant and adjusted superplasticizer content to have constant flow time. We kept superplasticizer dosage (relative to cement content) constant and adjusted water content to have constant slump. Higher superplasticizer dosages, provided the paste does not segregate, should result in more efficient strength performance of the cement.

Messrs de Larrard and Marchand claim that the difference between the results depicted in their Figures 1 and 2 "clearly emphasizes the fact that the cement-water ratio/compressive strength relationship obtained for cement paste mixtures can be quite different to that obtained for mortar (and presumably concrete) mixtures. On the other hand, the results by Marchand question the basis of the cement saturation concept."

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On the basis of data presented in their Figures 1 and 2, it is difficult to unequivocally support this statement. As pointed out above, data in their Figure 1 are too sparse to indicate anything. Their Figure 2 contains only four points.

It appears from the discussion of Messrs de Larrard and Marchand that they have misconstrued aspects of our paper. To quote: "In the model proposed by Addis and Alexander, it is supposed that the cement is fully hydrated in mature concrete, whatever the value of C/W." This is incorrect. What we do say is that full hydration is assumed for $C/W \leq 2.5$ and that for $C/W < 2.5$ full hydration is prevented by lack of space.

The degree of hydration of paste at W/C = 0.30, as quoted by Messrs de Larrard and Marchand, is about 60% according to Sellevold and Justnes. It should be noted that this value is not absolute but based on various assumptions. Also, the value is for sealed specimens, i.e. not cured in water. Sealed pastes at low W/C stop hydrating once the initial mixing water is used up by hydration and to fill the gel pores (self desiccation). At W/C = 0.3, the degree of hydration would be limited to about 60% by this mechanism if the paste is cured under sealed conditions.