Turning Marginal Aggregates into Useful Concrete Components

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1 Introduction

There is increasing pressure to use marginal aggregates for the production of cementitious systems which is motivated by environmental considerations and the depletion of high-quality resources.

Within this context, special attention is given to replacement of fine natural aggregate (sand) in view of the depletion and limitations in quarrying natural material. A major source for replacement is crushed aggregate, known as industrial graded sand, as well as sand which is obtained from various sites where excavations are taking place. The full efficient utilization of such sources of sand is often limited by regulations regarding the presence of large quantities of material smaller than 75 or 63 microns, which are often considered as deleterious dust, as well as contamination of clays. The usual practice is to wash away these materials, and they are being piled up as wastes, leading to an environmental burden on top of the washing process itself which is wasteful in nature. There is interest in allowing incorporation of higher levels of such micro-fines in the concrete, with special focus on the standard methylene blue test for detection of clays, the effects of clays on rheology and on the general properties of cementitious systems, as well as the use of admixtures to mitigate the negative influences of clays and micro-fines, e.g. [1–8].

The advancement in concrete technologies, especially high strength and self compacting concretes, are to a large extent based on efficient use of fillers, having size smaller than 75 microns, in combination with water reducing admixtures which disperse the fillers and turn them into useful component, both at the fresh and hardened state, improving workability and strength and reducing permeability. Normal strength concrete is produced presently with water reducing admixtures and thus there is room to consider this state of affairs to mobilize micro-fines in aggregates which exceed the current standard limitations as fillers, by incorporation of adequate admixtures. This implies a revision in the approach to aggregates, by considering their composition as well as the admixture technologies to be used in the concrete, to optimize the whole pipe-line, ranging from the aggregates to the concrete. The feasibility of this holistic approach was the object of the present study which evaluated crushed fine aggregates

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obtained from local quarries in Israel, in which the micro-fines content was high, as well as presence of swelling clays, all beyond the standard limits.

2 Overview of Research and Testing Program

The study included two parts, the first one dealing with characterization of micro-fines obtained from various sources and studying their mineralogy, particle size and the rheological behavior in mortars prepared with "engineered sand", which was made up of high quality siliceous sand in which replacements of up to 30% by the various micro-fines were implemented.

The second part included study of the rheological properties of concretes made with these micro-fines and adjustment of their fresh properties to obtain adequate workability (similar to reference concrete) by adjustment of admixtures: lignosulfonate, polycarboxylate and clay mitigating admixture (CMA).

The current paper presents part of the results, only those which are relevant to engineering practices and considerations for modifications in the standards.

3 Microfines Characterization

The micro-fines contained a range of montmorillonite clays, up to about 10% by weight, which corresponds to methylene blue values (MBV) higher than 7. Based on calibration curves of methylene blue vs. montmorillonite and kaolinite clays contents, the equivalent montmorillonite content could be calculated from the MBV, and reasonable agreement between that value and the one obtained by XRD were found. The effect of the micro-fines content and their MBV on the yield value was determined in rheological tests (1:3 mortars at a constant w/c ratio of 0.70). The curves can be classified into 3 types, based on the nature of the relation between the yield value and the micro-fines content of the engineered sand. In type I (Low MBV, less than 3), the curve increases monotonously, up to the highest micro-fines content studied, 30%. In type II (Medium MBV, between 4 and 6), the curve increases monotonously, at a rate higher than type I, and at about 25% micro-fines content it shows a turning point of a sharp increase. In type III (High MBV, bigger than 7), there is a steeper monotonous increase and the sharp turning point takes place at a lower micro-fine content of about 15%.

The differences between the three categories can be observed alternatively, in more "friendly" engineering terms, by determining the increase in the mortars water demand for 20% micro-fines content engineered sand, as a function of the MBV, Fig. 1.

For type I, the increase in water demand is about 8%, and it remains constant up to about MBV of 3, in type II it increases gradually to about 13%, and at type III the increase is very sharp.

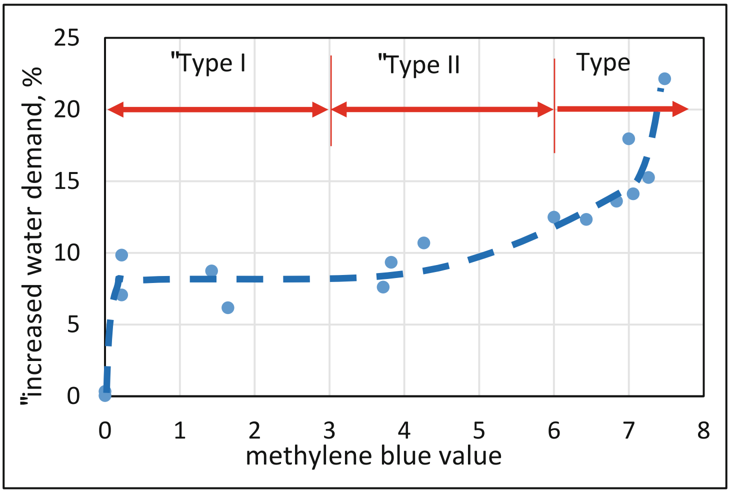

Fig. 1. The increase in water demand of mortars prepared with engineered sands containing 20% different types of micro-fines, as a function of their MBV

4 Concretes

The three categories identified in Fig. 1 were reflected also in the means which need to be taken with regards to reducing the water content to the level of the reference concrete. In the case of Type I and II, water reducing admixtures were sufficient (lignosulfonate or polycarboxylate), while in type III there was a need to use a combination of polycarboxylate and CMA.

The study of concretes resolved that in the mix design the more relevant inputs should be the total content of micro-fines in the concrete rather than the micro-fines content in a specific aggregate, as shown in Fig. 2. This figure presents the type and content of admixture required to obtain workability (slump or yield value) similar to the reference concrete, as a function of the content of the micro-fines and their nature (low, medium and high MBV).

It can be seen that for the low and medium MBV either lignosulfonate or polycarboxylate was sufficient. There seems to be a threshold level of micro-fines, in the range between 100 and 150 kg/m^3, where transition from lignosulfonate to polycarboxylate is required; contents of lignosulfonate bigger than about 1% by weight of cement induced retardation, and that is where the transition threshold was placed. Above the threshold, the content of polycarboxylate required increased with the micro-fines content, and the range of admixture contents in the figure reflects the differences between the types I and II micro-fines (low and medium MBV). The type III micro-fines (high MBV) required combination of polycarboxylate and CMA. The CMA required was found to be about 1/3 of the content of equivalent montmorillonite, as calculated from the MBV.

The tests of mature concretes with micro-fines and optimal admixture indicated that filler effects could be mobilized, as indicated by microstructural observations and

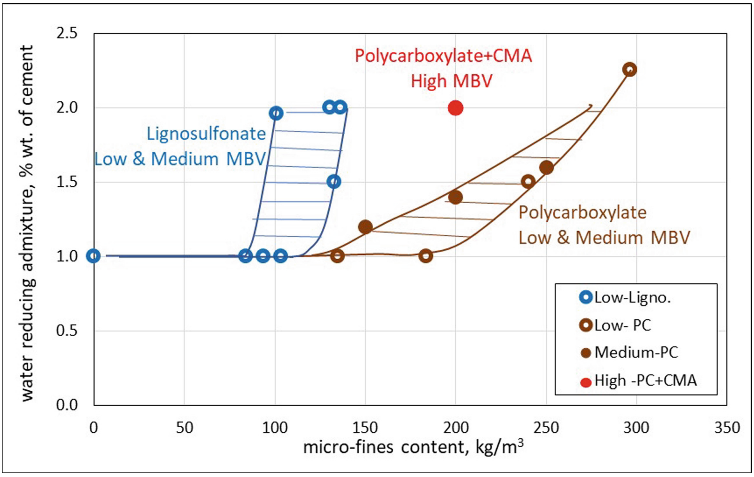

Fig. 2. The content and type of admixture required to achieve workability similar to reference concrete as a function of the content of micro-fines and their nature as determined by the MBV

strength determination. In concretes with micro-fines content bigger than 100 kg/m^3 the strength gradually increased above the reference concrete having the same w/c ration. The strength gain at 28 days is about 30%, while at one day the strength gain was even higher. The higher strength at early age could be related with the effects of the carbonate and dolomitic micro-fines on acceleration of hydration reactions.

Shrinkage tests demonstrated that at the optimum admixture contents the shrinkage was practically independent of the micro-fine content.

5 Conclusions

- In order to mobilize effectively the use of marginal aggregates with high micro-fines content there is a need for a holistic approach, considering the whole pipeline of the aggregates and concretes, which should be based on concrete performance rather than aggregate composition.
- Micro-fines can be categorized into three types, depending on their MBV, low (<3), medium (4–6) and high (>7), showing differences in increased water demand at each category.
- The strategy for neutralizing the effect of micro-fines on increased water demand in concrete can be quantified in terms of combination of their content in concrete and their MBV.
- The effect of low and medium MBV aggregates on the water requirement can be neutralized by lignosulfonates when their content in the concrete is below a threshold value of about 150 kg/m^3, and polycarboxylates are required at higher content; for high MBV aggregate, combination of polycarboxylate and CMA is required.

- At the optimum admixture content and type, beneficial effect of strength increase is obtained, due to mobilization of a filler effect of the micro-fines. This strength increase can be considered in terms of economic effect, to counteract the added cost of the required admixtures.

References

1. Katz, A., Baum, H.: Effect of high levels of fines content on concrete properties. ACI Mater. J. **103**, 474–482 (2006)
2. Quiroga, P.N., Ahn, N., Fowler, D.W.: Concrete mixtures with high microfines. ACI Mater. J. **103**, 258–264 (2006)
3. Nehdi, M.I.: Clay in cement based materials: critical review of state of the art. Constr. Build. Mater. **51**, 372–382 (2014)
4. Yukselen, Y., Kaya, A.: Suitability of the methylene blue tests for surface area, cation exchange capacity and swell potential of clayey soils. Eng. Geol. **102**, 38–45 (2008)
5. Fernandes, V.A., Purnell, P., Still, G.T., Thomas, T.H.: The effect of clay content in sands used for cementitious materials in developing countries. Cem. Con. Res. **37**, 751–758 (2007)
6. Tregger, N.A., Pakula, M.E., Shah, S.P.: Influence of clays on the rheology of cement pastes. Cem. Concr. Res. **40**, 384–391 (2010)
7. Norvell, J.K., Stewart, J.G., Juenger, M.C.G., Fowler, D.W.: Influence of clay-sized particles on concrete performance. ASCE J. Mat. Civ. Eng. **19**, 1053–1059 (2007)
8. Jeknavorian, A.A., Jardine, L., Ou, C.C., Koyata, H., Folliard, K.: Interaction of superplasticizers with clay-bearing aggregates. In: Malhotra, V.M. (ed.) Proceedings of the 7th CANMET/ACI International Conference on Superplasticzers and Other Chemical Admixtures in Concrete, Special Publication (SP-217). American Concrete Institute (2003)