COMBATING ASR TO ENABLE USAGE OF LOCAL AGGREGATES IN TURKEY

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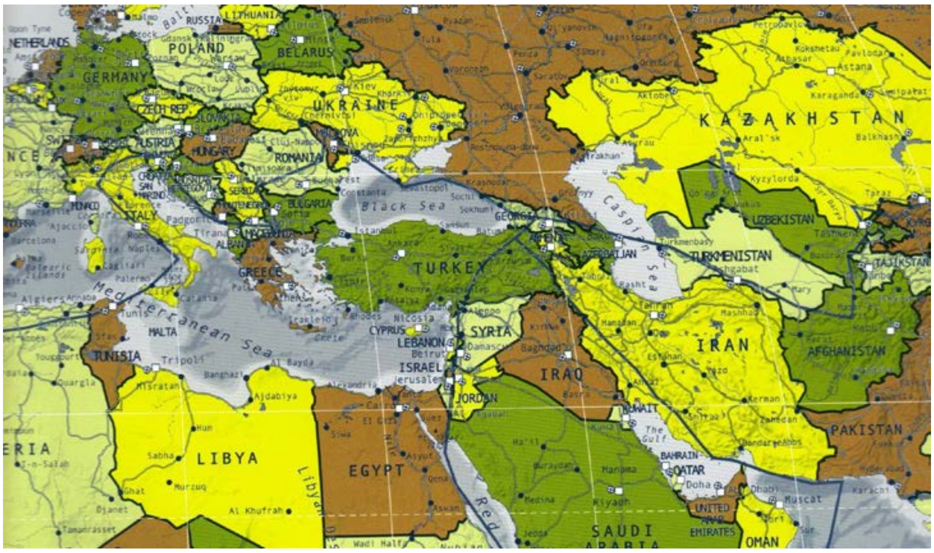
Abstract

This paper will look at the use of silica fume to negate the high reactivity of aggregates in Turkey. Reference will be made to initial testing for ASR resistance in the early 1970's, then to local research by KGM in 2013/2014 and further testing in Iceland in 2015. The paper will show that the addition of silica fume in the area of 8% by weight of cement will control the ASR within the specified limits and enable the use of local aggregates, with known reactivity potential, in major concrete construction. Further research is expected to establish levels at which even higher reactivity aggregate may be safely used.

Keywords: Alkali silica reaction (ASR), pozzolans, silica fume, expansion values.

1. INTRODUCTION



A central position – from the ancient to the modern world.

Turkey is at the junction of the European and Asian continents – a crossover for travelers for millennia – and to maintain that “fulcrum point of the world”, is looking to improve its infrastructure and communications. To do this means a lot of building from scratch and a lot of upgrading. This includes airports, dams, roads, bridges and tunnels, ports and harbours and power services.

The airport network alone is a huge system to upgrade (from Turkish Airlines)

Such construction will use huge quantities of concrete, nominal and high performance, which will in turn mean vast tonnages of aggregates. The drawback to this is the reactivity level of the majority of aggregate in Turkey. The potential for Alkali Silica Reaction (ASR) from these aggregates means that a number of precautionary steps must be taken to prevent the reaction happening and causing damage and possible failure of structures. The alternative is to ship in low reactivity aggregates to blend with local materials and thus reduce the potential for ASR. With the aggregate tonnages being registered in many tens of millions, such action would be costly and unfriendly to the environment. Readymix Concrete Production Volumes for the past few years have been approximately:

- 2010 ~ 80 million m^3
- 2011 ~ 91 million m^3
- 2012 ~ 93 million m^3
- 2013 ~ 100 million m^3
- 2014 ~ 110 million m^3

At approximately 1,800kg of aggregate per cubic metre, the last couple of years have approached some 200 million tonnes of aggregate consumption. At even a 50:50 blend with a low reactivity aggregate, the import potential would be around 100 million tonnes. The use of pozzolans has long been known to combat ASR with silica fume being widely acknowledged as the highest effectiveness in resisting this form of concrete deterioration. The target behind the research discussed in this paper is that being able to control the ASR potential, using silica fume, will mean that more local aggregates can be used, negating the need for import and thus reducing both the cost of the construction and the damage to the environment.

2. HISTORY

Since the early 1970s when large scale filtering meant that sufficient volumes of silica fume were available for the concrete industry, research has been conducted on how to make the best use of its pozzolanic action. The superfine nature and high silicon dioxide content of the silica fume gave it two advantages in combating the ASR attack. The small size and perfect spherical particles gave both a packing effect – filling the voids between cement grains – and a ball bearing effect to give cohesion but also a thixotropic effect. Once the calcium hydroxide was produced by the cement hydration, the pozzolanic reaction took over filling the void space with calcium silicate hydrates adding more bond within the matrix and blocking the pores in the cement. This meant a dense concrete with high water resistance and the pozzolanic action mopped up excess alkalis ions and calcium hydroxide (Fig 1). Thus, three parts of the quartet required for ASR were greatly reduced or negated and thus the ASR was controlled. It was in 1979 that Iceland, with its highly reactive aggregates and high alkali cement ruled that all concrete made with local materials must contain 7 to 8% silica fume to combat the ASR (Fig 2).

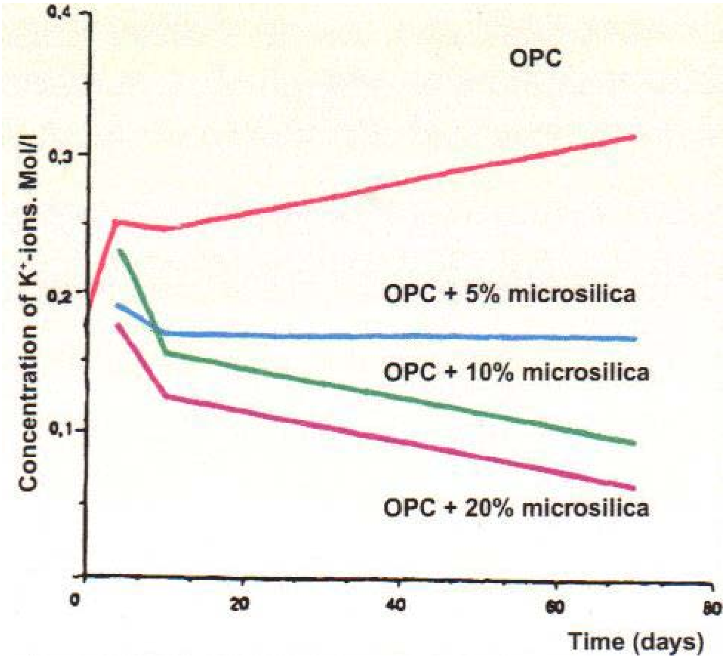


Figure 1: Reduction in Alkali ions with the addition of silica fume [1]

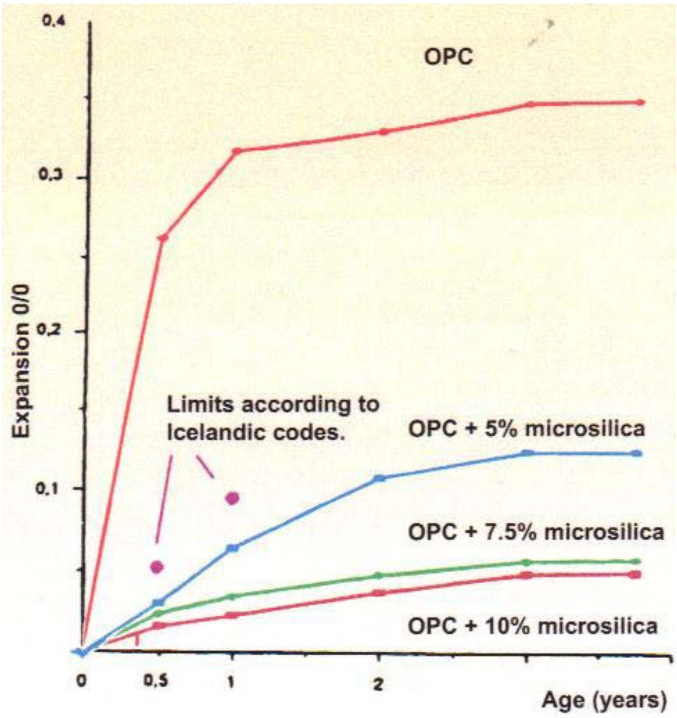


Figure 2: Reduction in Expansion with the addition of silica fume [2]

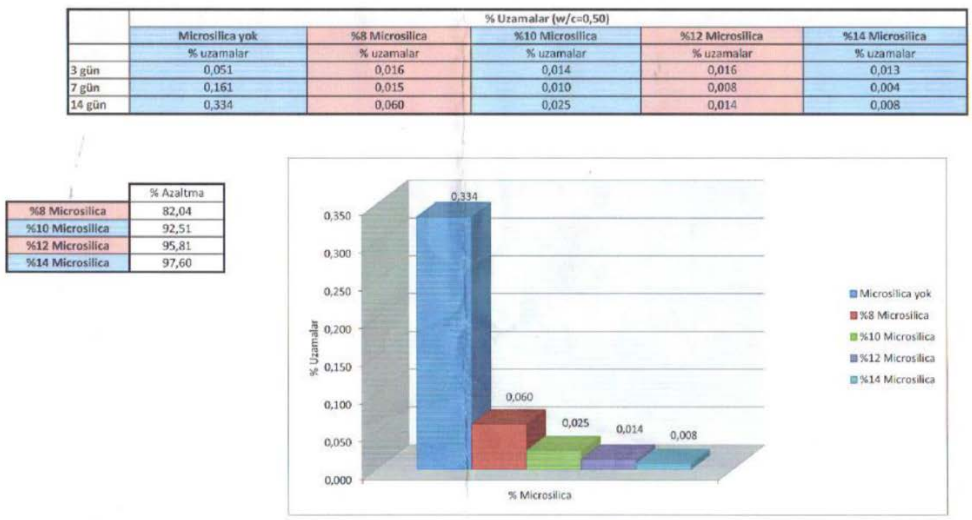
3. RESEARCH IN TURKEY

The use of concrete for roads and bridges and similar infrastructure in Turkey is covered by the current Highways Manual. The limitation on ASR expansion in this manual is 0.20% to allow aggregates to be used. As many of the local aggregates are around 0.30% to 0.50% expansion this becomes a difficult target. With some aggregates tested at around 0.80% expansion, the need for a solution to be able to use these increases. The Government Authority, DLH, through the KGM Highways department decided in 2013 to run some testing on the use of silica fume as an addition to concrete to combat the potential ASR with local materials. Using the Standard 14 day test and measuring the expansion for a series of silica fume dosages, the KGM research showed a very effective pattern of suppressing the ASR expansion, Table 1.

Table 1: Expansion values (%) by age and addition of silica fume [3]

Age \ SF	**0**	**8%**	**10%**	**12%**	**14%**
3 days	**0.051**	**0.016**	**0.014**	**0.016**	**0.013**
7 days	**0.161**	**0.015**	**0.010**	**0.008**	**0.004**
14 days	**0.334**	**0.060**	**0.025**	**0.014**	**0.008**

The values obtained showed that the use of silica fume at an 8% addition (by weight of cement) would limit the expansion of this level of reactive aggregate (0.30~0.40%) down to below 0.10%. This is half the target maximum of the Highways Manual. The values also showed that for each additional 2% of silica fume, the expansion at 14 days reduced by 50% from the previous level. The findings suggest that it may even be possible to use a dosage of between 8 and 10% silica fume to control reactive aggregates with values of 0.60 to 0.80%, reducing that expansion down to below 0.1%. A graph of the data is shown in figure 3.



	% Uzamalar (w/c=0,50)				
	Microsilica yok	%8 Microsilica	%10 Microsilica	%12 Microsilica	%14 Microsilica
	% uzamalar	% uzamalar	% uzamalar	% uzamalar	% uzamalar
3 gün	0,051	0,016	0,014	0,016	0,013
7 gün	0,161	0,015	0,010	0,008	0,004
14 gün	0,334	0,060	0,025	0,014	0,008

	% Azaltma
%8 Microsilica	82,04
%10 Microsilica	92,51
%12 Microsilica	95,81
%14 Microsilica	97,60

Figure 3: Tables and graph reproduced from KGM data [3]

The research at DLH / KGM is continuing to refine the levels of addition of silica fume needed for different types of reactive aggregates. The work may also include the use of other pozzolans such as fly ash or slag – also known to provide a level of resistance to ASR. The combination of these supplementary cementitious materials can achieve very high durability as well as numerous improvements to the concrete quality. It is hoped that this research will lead to the adoption of silica fume use within the Highways Manual.

4. WORK IN ICELAND

Although Iceland uses silica fume to suppress the ASR, it is known that new sources of aggregates can require changes in the addition rate to maintain a level of confidence in the concrete quality. Over the years since 1979 the addition rate of silica fume has reduced slightly – with the use of other materials and better superplasticisers – to around 6% by cement weight. Like Turkey, the idea is to blend high and low reactivity aggregates to get the best environmental sustainability and use the silica fume to ensure low expansion. A new sand source (Stokksnessandur) became available recently and testing showed that this had a potential expansion of between 0.40 and 0.50%. A 50% blend of this sand with a relatively inert sand (Raudamelssandur) would be the normal method of helping to control the ASR with the use of silica fume. Tests run at the Innovation Centre Iceland's 'Rheocenter' showed that even at the 50% blend the addition of silica fume would have to be increased to approximately 8% (Figure 4, Ref 4.). To use the Stokksnessandur sand at 100%, rather than 50:50, would require an addition of silica fume at 9% to stay below 0.20% expansion or 11% to reach less than 0.10% expansion.

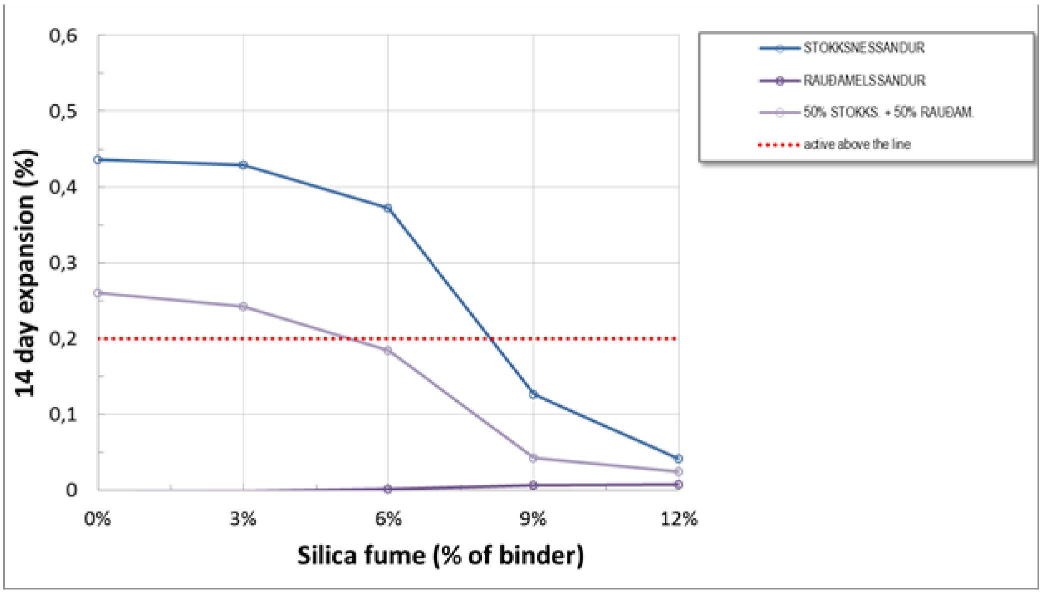


Figure 4: Expansion of individual and blended sand mixes with increasing silica fume [4]

5. SUMMARY

The current work in both Iceland and in Turkey substantiate the early results from the 1970s and 1980s, that show ASR can be resisted using silica fume as an addition to concrete. With 'moderately reactive' materials (0.30~0.40% expansion), this addition rate is around 8% by weight of cement. Higher reactivity aggregates can also be controlled in this manner, although test runs should be made to determine the optimum addition of silica fume.

The use of silica fume in concrete in Turkey should be highly considered by the authorities, in order to allow previously ‘unusable’ aggregates to be used, thus saving costs, energy and the environment through non-import of less reactive materials.

ACKNOWLEDGEMENTS

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