RECYCLING OF CONCRETE WITH ALKALI-REACTIVE AGGREGATE.

A.Nielsen, F.Gottfredsen, F.Thøgersen
Building Materials Laboratory,
Technical University of Denmark.

In order to use crushed alkali-reactive concrete as coarse aggregate in recycled concrete it is important to make sure, that proceeding reactions does not cause damages in the new structure. Accelerated tests have been initiated to examine the possible expansion of recycled concrete in dependency of residual reactivity of the old concrete and quality of the new mortar phase.

INTRODUCTION

As a consequence of the growing awareness of environmental protection it is the aim of the Danish government, that 50 % of the demolition rubble in the construction sector must be recycled by the year 2000. As a very large proportion of the building waste is concrete, it is of crucial importance for the fulfilling of this target, that crushed old concrete can be used as aggregate for new concrete, without causing deleterious damages in the structure.

During the past 25 years recycled concrete has been studied by a number of researchers [1], and it has been established (bearing in mind the special properties of crushed concrete compared to natural aggregates), that it is possible to recycle concrete in a dry environment. This recognition led to a Danish recommendation for recycling of concrete in passive environmental class [2]. When recycled concrete is placed outside, i.e. exposed to water and frost, two special problems have to be dealt with. On one hand the frost resistance of recycled concrete still have to be clarified, and on the other hand the susceptibility towards alkali-silica reactions is unknown. The subject of the present investigation is the latter problem, which has been scrutinized very little previously. The only project that can be found in the literature is an investigation made by the Transportation Research Board concerning recycled pavement concrete in Arizona, USA [3].

BACKGROUND

In Denmark a very large proportion of the concrete which is available for recycling is originally cast with alkali-reactive aggregate. This is a logical consequence of the fact, that most of the natural Danish aggregate has a high silica content. Furthermore it is evident that the concrete to be recycled has an age of at least 20 years, and at the time of construction the precautions needed to avoid ASR was not yet commonly known and used.

In order to asses the potential ASR-reactivity of a concrete subjected to recycling, it is desirable to know the original mix-design and the environment where the concrete has been placed. With this knowledge 4 different types of concrete can be proposed:

1. Concrete made with non-reactive aggregate.
2. Concrete made with reactive aggregates where the reactions have stopped due to lack of alkali or silica.
3. Concrete made with reactive aggregates where the reactions are still taking place, i.e. still expanding.
4. Concrete made with reactive aggregates where the reactions have not yet started because the concrete has been placed in a dry environment with insufficient moisture or alkalis.

It is obvious, that concrete of the first type can be recycled without further precautions. This is also the case concerning the concrete where the reactions have stopped due to lack of silica. When the reactions have stopped because of insufficient amount of alkalis it is not unlikely that the concrete can cause problems when recycled and placed in another environment. The concrete type 3 and 4 are potentially deleterious when recycled.

The degree of harmfulness of a given concrete can be judged by evaluating the residual reactivity. This can be done by accelerated expansion tests on prisms cut out of the concrete or by chemical shrinkage measurements. These methods will be dealt with in other conference contributions.

RECYCLED CONCRETE WITH REACTIVE AGGREGATE

The aim of the present investigation is to evaluate whether, and to what extent, it is possible to substitute natural sound aggregate with crushed reactive concrete. This substitution is only relevant for particles greater than 4 mm, as the strength and workability properties of fine crushed aggregate are very poor. The crushed concrete particles greater than 4 mm will be embedded in a new sound mortar using a non-reactive sand.

The majority of damages due to ASR in Denmark are caused by reactive particles in the sand fraction. These dangerous grains will be present in the mortar phase attached to the coarse particles in the recycled aggregate. This situation with reactive particles concentrated in lumps is shown in fig. 1.

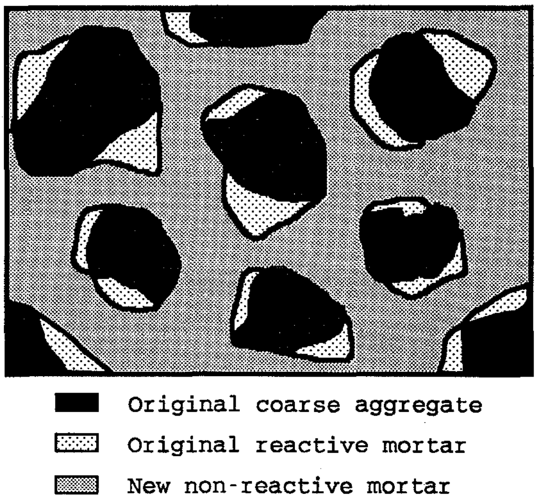

Figure 1: Recycled concrete, in principle.

The question is whether the reactive particles in the mortar phase of the old concrete will be able to expand and thereby cause cracking in the new mortar. Compared to the original, perhaps damaged concrete, the reactive material have been diluted, and may therefore be innocuous when surrounded by a strong, sound mortar. However this dilution is not uniform, i.e. the reactive particles still maintain their original spacing, and are not evenly distributed in the concrete. The stress development around the reactive particles will be analyzed using a static-geometrical model described in [4] and [5].

In order to evaluate the risk of deleterious alkali-silica reactions in recycled concrete a number of things have to be considered. As it was mentioned above the residual reactivity of the crushed concrete is of great importance. This concept indicates the amount of available reactive silica. Furthermore the distribution of reactive particles is of interest. With an increasing grain size of the crushed coarse aggregate the dilution effect is diminished.

The properties of the new mortar surrounding the crushed particles also affect the risk of damages. With a high tensile strength, it is less likely that the tensile stresses around the expanding grains will cause cracking. The porosity and permeability of the mortar determines the migration of alkalis and water towards the reactive grains. Both strength and imperviousness are enhanced by lowering the water-cement ratio, and therefore it might be expected that a sufficiently low w/c ratio will prevent cracking. Another way of improving the mortar is to add a puzzolan like fly-ash. This will both lower the permeability and, as it is recognized by most researchers, diminish the amount of damaging alkali-silica reactions due to an alkali-binding effect. Finally the environment, in which the recycled concrete is placed, i.e. the moisture and alkali exposure from the exterior, has a great bearing on the risk of damages.

EXPERIMENTAL PROGRAMME

In order to investigate recycled concrete with ASR a series of experiments has been started. The experimental method chosen is a modified version of the accelerated mortar bar test ASTM C-227. Concrete cylinders (200mm,ø100mm) has been cast, using various types of crushed concrete as coarse aggregate. Initially the cylinders were stored in water for 28 days at 20 °C. They were then moved to a saturated sodiumchloride solution at 50 °C. In the testing period the concrete cylinders will be measured and weighed at given terms. The length changes will indicate the development of ASR in the concrete. The weight changes are also expected to be correlated to the amount of ASR, as water enters the cylinders and fills up the voids and cracks formed by the reactions. The weight gain is further increased by the waterabsorbing capacity of the AS-gel.

The recycled concrete has been made with four different types of crushed concrete as coarse aggregate. It has been attempted to use concrete of the four types listed earlier. One was cast with a non-reactive sand and non-reactive granite (no reactions expected, type 1). Another concrete was made using a very reactive sand with a high content of opaline silica (type 4). The third concrete quality was made using crushed cores taken from a pavement concrete which was severely deteriorated by ASR (type 2 or 3). Finally another old concrete (type 2 or 3) from a demolition site was used. Two different maximum grain sizes of the crushed concrete were used: 16 and 32 mm.

The influence of the mortar quality is examined by using two w/c ratios: 0.45 and 0.55, corresponding to the values normally used for outdoor concrete. Likewise a cement with low alkali content has been chosen, as this is the cement type which will be used in practice. The effect of adding puzzolanes is investigated by making mortars with 0 and 35 % fly ash, as a percentage of the total amount of cement and fly ash; 35 % being the maximum amount allowed according to the Danish specification for concrete durability [6].

Finally the influence of two other factors, namely air entrainment and initial cracks will be analyzed. It is expected, that an air content sufficiently high to make the concrete frost resistant, will also diminish the expansion due to ASR. As opposed to this it is expected, that initial surface cracks originating from the construction period will advance the imbibition of water and alkalis, and thereby cause earlier and more severe reactions.

Parameter	Value
Cement type	low alkali
Water/cement - ratio	0.45; 0.55
Maximum grain size	16; 32 mm
Fly ash content	0; 35 vol-%
Reactivity of crushed concrete	4 types
Air content	~1; ~5 vol-%
Initial cracks	yes; no

Table 1 : Parameters involved in the experimental programme.

PRELIMINARY RESULTS

Initially it must be stressed, that at the time of printing the measurements have only been proceeding for about three weeks. This means that only a few tendencies can be deduced from the results. Bearing this in mind, it looks like the adding of flyash, as it was expected, reduces the expansions markedly. Further it is obvious that the more reactive concrete qualities have the larger expansions, but the magnitude is not yet critical (less than 0.2 o/oo after two weeks). Finally there seems to be a reasonable correlation between expansion and weight gain of the cylinders.

ACKNOWLEDGEMENTS

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