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Waste Materials in Construction: Putting Theory into Practice

TEST PROJECT "CRUSHED MASONRY 50/150 mm IN THE VENTJAGERSPLAAT RIVER DAM"

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Abstract: The suitability of crushed masonry as a core material in hydraulic engineering structures has been examined during the Ventjagersplaat test project. A rock-fill dam was built to protect the Ventjagersplaat in September 1992. The South Holland Directorate of the Ministry of Transport, Public Works and Water Management (RWS) gave permission for approximately 150 metres of the core of this dam to be built with 50/150 mm crushed masonry instead of rock rubble. The use of crushed rubble for the core material in dams of this type is considered acceptable based upon the results of the Ventjagersplaat test project. Dams of this type are subject to relatively less stringent requirements. For possible application in comparable projects a number of recommendations are made in this article concerning the requirements to be imposed.

1. Introduction

To comply with the terms of the Building and Demolition Waste implementation plan of the Ministry of Housing, Planning and the Environment the reuse of building and demolition waste should rise from 6.8 million tons in 1990 to approximately 12.2 million tons in 2000. To achieve this, "new" markets must be developed. This applies particularly to the largest component of building and demolition waste, masonry waste. An application of crushed masonry, for which there are many opportunities, is as the core material in dams. To demonstrate this, the South Holland Directorate of the RWS made a test location in the Haringvliet available in 1992.

2. Aims of the test project

The test project had the following aims:

- enhancement of the opportunities for the use of crushed masonry.
- demonstration of the structural and practical feasibility of the application as the core material in dams.
- gaining an understanding of the effects upon costs when crushed masonry is used instead of rock rubble.

3. Ventjagersplaat test project

The test project involved the application of crushed masonry in a dam to be newly built on the western side of the Ventjagersplaat. For this application a 150-metre length of the core of the dam was built using 50/150 mm crushed masonry instead of 50/150 mm rock rubble. All of the dam exterior surface was covered by 10-60 kg rock rubble.

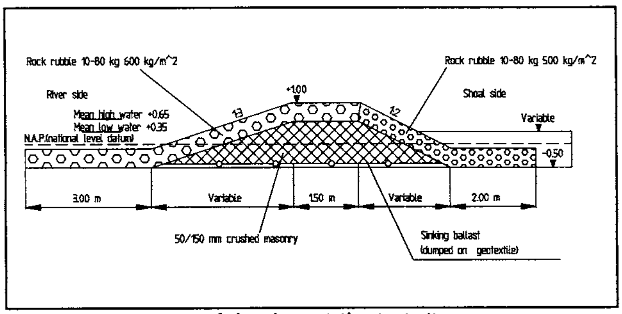

Fig. 1: Cross-section of the dam at the test site

The dam structure is shown in Fig 1. The work was necessary to protect the shoal, used as a feeding ground by birds, from attack by currents and waves. A batch of approximately 720 tons of 50/150 mm crushed masonry was produced in three days at a building and demolition waste processing establishment. This batch consisted of approximately 60% brick, 40% concrete and 2% of other components. There were almost no pieces retained on the 180 mm sieve from the batch of 50/150 mm crushed masonry. In addition, the content of flat pieces was very high. This was caused by the basic material used and the limited facilities at the crusher for crushing coarsely enough. It is advisable, by discussion with the clients and the building waste processor, to reach a proper balance between, on the one hand, the requirements and wishes of the clients and on the other, the facilities of the crushing plant.

4. Aspects of the execution

Execution of the project took place in September 1992. From the first results of the test project it was concluded that the application of 50/150 mm crushed masonry was a good alternative for the core material in the building of dams. During the execution of the work using crushed masonry as the core material no significant differences were found with rock rubble concerning ease of processing, suitability for vehicular traffic and stability. The loads imposed by the action of waves and currents have not produced any visually-observable damage. It was, however, necessary to remove any floating wood and aerated concrete from the structure manually. There was, as a result of the washing out of brick dust, a red colouration of the water, but this disappeared after one day.

Schematically, the loads imposed during execution can be seen as loading/dumping six times and driving over four times. A degradation of the material occurred as a result of the loading during execution: the D_{50} (median sieved size) fell by approximately 20% which corresponds with a "here to there factor" of 0.8. The degradation that occurred was, for the situation examined, acceptable in every respect.

It appeared that, when driven over a thin layer of crushed masonry on a hard surface (in this case a hardened foundation), there was clearly powdering.

Degradation of the crushed masonry was simulated by drop tests. These showed that the extent of degradation, particularly at the start, was determined markedly by the presence of flat pieces in the crushed masonry.

Degradation of the crushed masonry can be limited by restricting the destructive transfer movements, preventing vehicular traffic over it and keeping the content of flat pieces low.

5. Structural suitability

Los Angeles Abrasion

As a measure of the material strength the Los Angeles Abrasion value (LAA value) of the basic material (composition approximately 60% brick/40% concrete/2% other components) was determined. The LAA values were also determined for samples of the three separated types of material (concrete, brick and calcium silicate brick) taken before and after processing and after a period of three years in the dam core. Because the winters during the three-year monitoring period were mild, LAA values were also determined for pieces removed from the core and subjected to 25 freezing/thawing cycles according to NEN 5184. LAA values from 45 to 55% were found for the crushed masonry used. The LAA values measured for the three separated material types were fairly constant and were not changed demonstrably by placing in position, after three years practical loading and after freezing/thawing loading (see Fig. 2).

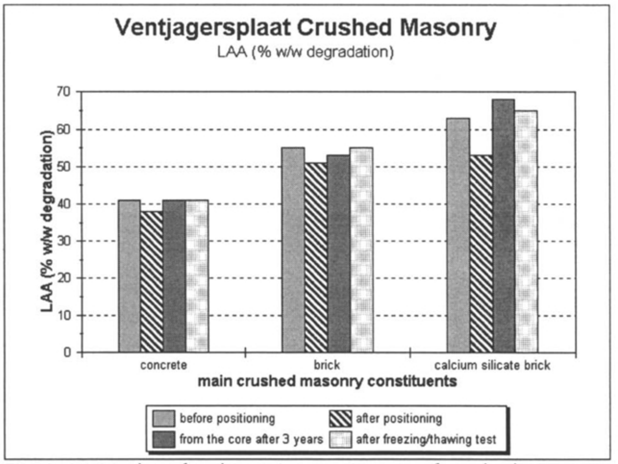

Fig. 2: LAA values for the main constituents of crushed masonry

Resistance to freezing and thawing

The resistance to freezing and thawing of the crushed masonry used, as a total for the three main components: concrete, brick and calcium silicate brick, is of the order of a 1.5 to 2% weight loss when tested according to NEN 5184. The winters during the three-year test period were relatively mild. It has been established that the freezing/thawing resistance did not fall during this period. The fall to be expected for the D_{50} as a result of freezing/thawing is small compared with the "here to there factor" found of 0.8.

Settling of the dam
No significantly different subsidence of the upper part of the dam was measured for the part where crushed masonry was used as the core material than for the part where rock rubble was used. Settling measurements were in the range from approximately 1 to 10 mm with a mean of between 3 and 3.5 mm. It should be noted that the mean subsidence with time (during the 46 months after construction), for both the part of the dam with a rock rubble core and the part with a core of crushed masonry, has hardly increased (see Fig. 3).

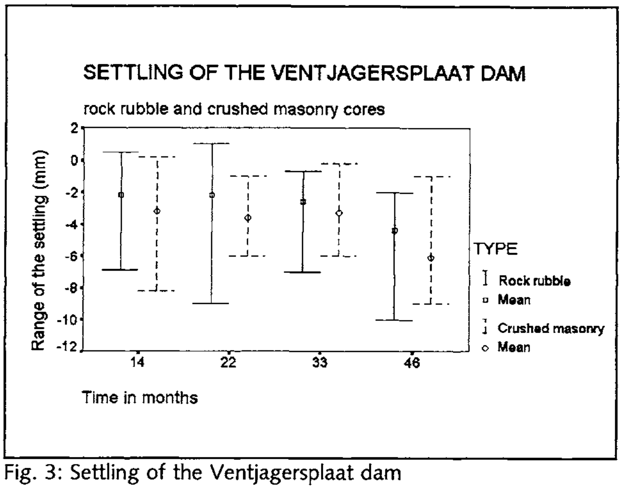

Fig. 3: Settling of the Ventjagersplaat dam

6. Recommendations for the requirements to be imposed upon crushed masonry as a core material for dams

Based upon the Ventjagersplaat trial project the application of crushed masonry as the core material for dams of this type, where the requirements can be relatively flexible, is considered to be acceptable. For a permissible fall in the D_{50} to 75 to 80% the following requirements are recommended and involve the mean properties of the batch:

- **composition:**
  (according to NEN 5942)

calcium silicate brick:	10% w/w maximum
brickwork + calcium silicate brick:	60% w/w maximum

The crushed masonry may not contain any parts that will remain floating in water.

- **flat pieces content:**
  (according to DWW-MAW-R81054) 40% w/w maximum

- **LAA value of the separate constituents:**
  (according to ASTM C-535)

concrete:	45% w/w maximum
brickwork:	60% w/w maximum
calcium silicate brick:	70% w/w maximum

Note that the permissible fall of the D_{50} must first be determined, so that after construction the filter requirements included in the design can still be met. In most cases a reduction by approximately 20% will cause no design problems. In special cases where only a lesser reduction is permissible it is advisable to make the flat pieces content requirement more stringent and to limit the number of destructive transfer movements.

7. Environmental aspects

The crushed masonry used came from a rubble crushing installation certificated by the Stichting Kwaliteitsborging Korrelmix [Aggregate Quality Guarantee Foundation]. The crushed masonry complied with the requirements in mid 1992 of the Building Materials Order that was then being drafted. Thus the crushed masonry could be used without restrictions in surface water. The material must be taken back by the owner if the works for which it has been used no longer have a function and/or they are no longer maintained. This applies in general to all Category 1 materials that have not been shaped into a form and for example, to rock rubble.

After the Building Materials Order comes fully into force in mid 1998 the producer will have to show that the granular material complies with the requirements of the Order. Before then the rules according to the IPO (Interprovincial Consultative Body) policy will apply.

8. Economic aspects

The cost of the crushed masonry delivered to the site (in 1992) was ƒ 31 /ton compared to ƒ 29 /ton for rock rubble. Nevertheless the use of crushed masonry based on m^1 of the dam to be built, is about 20% cheaper. This difference is caused by the fact that each metre of the dam's length needs fewer tons of crushed masonry (approximately 4.5 tons compared to 6 tons of rock rubble). This is a consequence of the lower density of crushed masonry (1900 kg/m^3) compared with the density of rock rubble (approximately 2600 kg/m^3). It should be noted here that about 45% of the cost of supply on the site of the crushed rubble arises from the higher transport costs as a result of an additional transfer.

9. Conclusions

The Ventjagersplaat test project has shown that the application of 50/150 mm crushed masonry in bulk quantities can be a good alternative structurally, environmentally and during construction to the traditional rock rubble as the core material in dams. In the period of examination of 3 years until now no indications have been found of a significant deterioration of the crushed masonry. It is considered acceptable, based on the Ventjagersplaat test project, to use crushed masonry as the core material in dams of this type for which the requirements can be relatively less stringent. Recommendations have been made, in connection with possible applications in other comparable projects, concerning the requirements to be imposed.

Parties involved

The test project was carried out under the responsibility of the CUR (Centre for Civil Engineering Construction, Research and Regulation) research committee B37 "Application of alternative materials in hydraulic engineering", working party 8 (applications) and supervised by the Ventjagersplaat project group. After the dissolution of committee B37 the responsibility for the test section was taken over by the Road and Hydraulic Engineering Department (DWW) of the RWS. During the execution of the project, in addition to the Ventjagersplaat project group, the following parties were represented: Aannemingsbedrijf Spaans en Zn of Werkendam (contractor), Brekerij Julianahaven of Dordrecht (masonry waste crusher), the South Holland Directorate of the RWS of Rotterdam and Fugro Consulting Engineers of Arnhem.

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