Use of recycled concrete as aggregate in normal concrete in Norway

Olav Lahus PhD[1]
Bente Lillestøl MSc [2]
Christine Hauck MSc [2]

[1] Norwegian Building Research Institute. P.O. Box. 123 Blindern. N-0314 Oslo. Norway. Phone: +47 22 96 55 55. Fax: +47 22 96 57 25. E-mail: olav.lahus@byggforsk.no
[2] Veidekke ASA. P.O.Box 505 Skøyen. N-0214 Oslo. Norway. Phone: +47 21 05 50 00. Fax: +47 21 05 50 01. E-mail: bente.lillestol@veidekke.no and christine.hauck@veidekke.no

INTRODUCTION

It has been estimated that approximately 50 million tons of concrete are currently demolished each year in the European Economic Communities and about 1 million tons are demolished in Norway according to Mehus et al. (2000).

For environmental and political reasons the number of readily accessible disposal sites around major cities in Norway are decreasing and have been restricted. For these reasons reuse of demolished concrete as aggregates for production of new concrete have been investigated both in the laboratory and in the field.

The utilization of by-products and secondary materials in normal construction concrete is influenced by economic factors like costs of transportation and the price of the alternative materials. The economic factors are estimated based on experience from a parking house and a school building in Oslo.

The quality of the recycled aggregate were investigated as well as the mechanical properties of recycled aggregate concrete with increasing amounts of recycled concrete aggregate. This involves both extended laboratory testing and long-term follow-up studies of existing full-scale demonstration projects.

RESIBA

RESIBA – Recycled Aggregates for Construction and Building is an EcoBuild project, which aims to make recycled aggregates a competitive product for a range of applications (http://www.byggforsk.no/Prosjekter/RESIBA/english/default.htm). The main objective of the RESIBA-project is to encourage long-term use of recycled aggregates for various applications within the Norwegian building and construction industry, thus reducing the impact for the industry on the environment. This article is based on the work of Work package 2: Demonstration projects, which aim is to evaluate the use of recycled aggregate in already completed construction projects as well as to launch pilot projects investigating the use of recycled aggregates in different types of concrete structures, roads and trenches. Main results are given in Lahus et al 2002.

USE OF RECYCLED AGGREGATE

Recycled aggregates

1.5 million tons of heavy building waste is produced in Norway each year (Statistics Norway ,1999a). About 2/3 of this consists of concrete and bricks (Figure 1). For comparison, about 6 million tons of natural aggregates is produced in Norway each year. Concrete and brick waste can be crushed and used on site or delivered for recovery of materials to specialized recycling plants and some crushed stone producers. But there are only a handful of specialized recycling plants in Norway that handle concrete and brick waste. In 1999, these plants recovered approx. 130 000 tones of concrete and brick (Statistics Norway ,1999b). Increasingly, concrete from demolished buildings is being crushed using mobile crushing machines and reused on site, for example, for landfill. The recycled aggregates may be used in structural concrete, sprayed concrete and building blocks.

Figure 1 After crushing and sieving the crushed concrete becomes useful recycled aggregates for concrete (Picture: Bente Lillestøl, Veidekke ASA)

Concrete

The yearly production of concrete in Norway is about 2 millions square meter, and 68 % of this consists of ordinary concrete quality C 35 NA with a characteristic compressive strengt og 35 MPa. According to Norwegian regulations (Norwegian Concrete Assosiation, 1999), 20 % of aggregate with D_{max} > 8 mm can be replaced by recycled concrete aggregate.

Figure 2 Production of concrete foundation with 20 % replacement of natural aggregates with D_{max} > 8 mm at the Fornebu Building site (Picture: Bente Lillestøl, Veidekke ASA)

During the construction of a new parking garage at Fornebu, the contractor incorporated the use of 20 % of recycled aggregates by replacing 20 % of the coarse aggregate in the concrete fundation (Figure 2). Concrete production and casting of the foundation were successful, and the laboratory test results showed that concrete met the material properties as specified (Lahus and Lillestøl, 2000). Both the production and use of recycled aggregate concrete satisfied the requirements set by both the estate developer and Norwegian concrete codes and Publication No. 26 from the Norwegian Concrete Association.

Laboratory testing of concrete quality C 35 and C 45 using up to 100 % recycled aggregates as a substitute for the coarse aggregate also yielded positive results (Lahus and Lillestøl, 2000a and Lahus and Lillestøl, 2000b). The mix designs are given in Table 1 and 2.

Table 1 Mix design concrete quality C 35

Material		Supplyer	C35 NA Lab	C35 NA Lab-20R	C35 NA Lab-40R	C35 NA Lab-60R	C35 NA Lab-80R	C35 NA Lab-100R
Fine agg. 0-8	kg/m^3	Norstone AS, Årdal	939	939	939	939	939	939
Coars agg. 8-11	kg/m^3	Norstone AS, Årdal	347	347	347	174	0	0
Coars agg. 11-16	kg/m^3	Norstone AS, Årdal	347	174	0	0	0	0
Coars agg. 16-25	kg/m^3	Norstone AS, Årdal	173	173	173	173	173	0
Recy. Coars agg.. 10-20	kg/m^3	BA Gjenvinning	0	173	347	520	694	867
Sement	kg/m^3	Embra Standard	319	319	319	319	319	319
Silica	kg/m^3	Elkem Silica	20	20	20	20	20	20
Scancem P	kg/m^3	Scancem	2	2	2	2	2	2
Scanflyt-2	kg/m^3	Scancem	2	2	2	2	2	2
Water	kg/m^3		192	192	192	192	192	192
Effective v/c+s			0,6	0,6	0,6	0,6	0,6	0,6

Table 2 Mix design concrete quality C 45

Material		Supplyer	C45 NA	C45 NA-20R	C45 NA-40R	C45 NA-60R	C45 NA-100R
Sand 0-8 mm	kg/m^3	Storsand	894	894	894	894	894
Pukk 8-22 mm	kg/m^3	Storsand	952	762	571	381	0
Resirk. 10-20 mm	kg/m^3	BA Gjenvinning	0	190	381	571	952
Sement	kg/m^3	Embra Standard	319	319	319	319	319
Silica	kg/m^3	Elkem Silica	20	20	20	20	20
BV40	kg/m^3	Sika	1,7	1,7	1,7	1,7	1,7
ECO2	kg/m^3	Sika	2,7	2,7	2,7	2,7	2,7
Water	kg/m^3	Kommunalt	176	176	176	176	176
Effectivt v/c+s [1)]			0,52	0,52	0,52	0,52	0,52

The mean compressive strength after 28 days were reduced down to between 85 and 90 % with 100 % recycled aggregates as a substitute for the coarse aggregate (Figure 3)

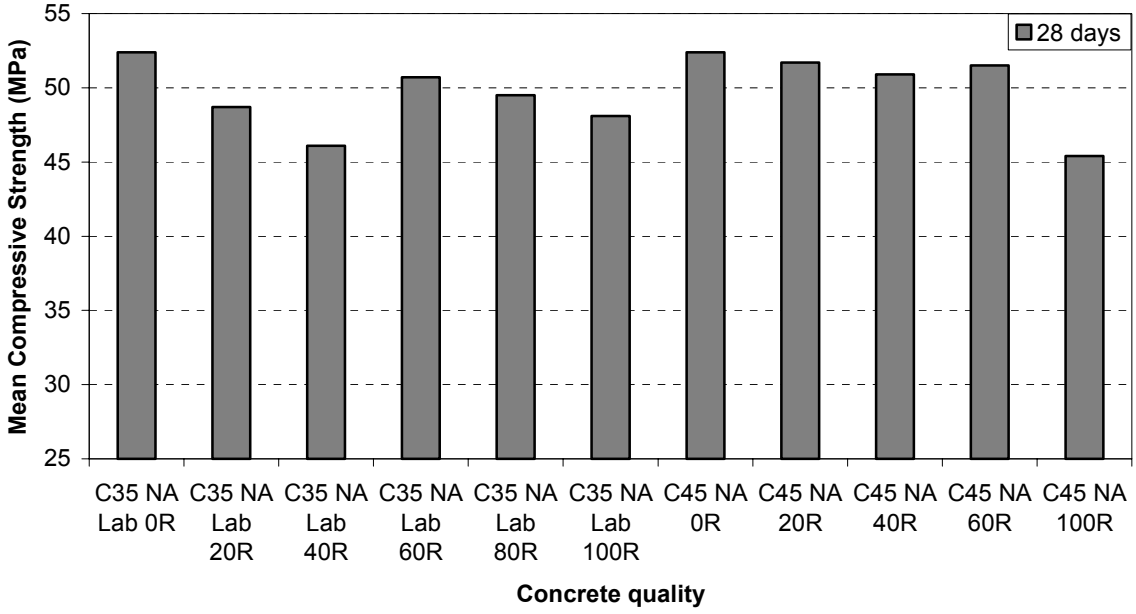

Figure 3 Mean compressive strength with increasing replacement of natural coarse aggregate at the Fornebu Building site (Picture: Bente Lillestøl, Veidekke ASA)

Shotcrete

Recycled fine aggregate (0-4 mm) were for the first time introduced in sprayed concrete with satifactory results (Figure 4) as reported by Farstad and Hauck (2001). This world's first employment of shotcrete incorporating recycled aggregates can be found at Oslo Sporveier's new tramline over Gaustadbekkdalen in Oslo were completed in 1999. The vertical sides of an EPS lightweight fill were protected by 100 m^2 shotcrete were up to 20 % of the sand was substituted by recycled aggregates according to Hauck and Farstad (2001). The contractor successfully conducted the spraying and the shotcrete met the material properties as specified. Both the properties of the fresh shotcrete and the mechanical properties were satisfactory as well as the durability characteristics. The compressive strength was reduced by 18 % with use of 20 % recycled aggregate.

Building blocks

Masonry sound insulation building blocks were produced using 30 % recycled aggregated 4-10 mm. Laboratory testing demonstrated that the results were satisfactory and in accordance with the technical spesifications (Figure 5). The marked will decide if further production will be initiated.

Figure 4 Sprayed concrete with recycled aggregates (0-4 mm) at the Gaustabekk Building site (Picture: Bente Lillestøl, Veidekke ASA)

Figure 5 Building blocks with 30 % recycled aggregates (0-4 mm) (Picture: Bente Lillestøl, Veidekke ASA)

COSTS

Recycled aggregates are moderate and the unit cost is typical 60-90 % of natural aggregates. According to economical estimates, use of recycled aggregates vs. natural aggregates in concrete, shotcrete and building block does not increase the material costs in the evaluated projects.

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