

CEN Technical Committee 104 SC1/TG19, *Use of RA*

Overview of use of RA in concrete in Europe and USA and applicable regulations.

Abbreviations used:

RA: recycled aggregate;

RCA: recycled concrete aggregate (in EN12620 renamed *crushed concrete aggregate*);

C&DW: construction and demolition waste;

NAD: national application document (national rules for application of standards e.g. EN206-1).

Introduction

This paper attempts to give an overview of some technical and regulatory considerations about the use of RA in concrete. It is based on papers circulated in CENTC/104/SC1/TG19 *Aggregates for concrete*, and on a questionnaire by ERMCO to its member associations. The questionnaire is as shown below.

COUNTRY:	
1. Which RA are allowed to be used in concrete in your country? (Coarse, fine? Etc.)	
2. Is anything other than crushed concrete used as RA (for example bricks, mortar)?	
3. What limits are there on types of structures, or on types or grades of concrete, where the use of concrete containing RA is allowed?	
4. Please give any data you have on volumes of concrete produced using RA? (In terms of percentage of total concrete volume produced.) Estimate if necessary.	
5. What is your opinion of the future? Is the use of RA likely to increase significantly?	
6. Are there any policy issues that affect your members' use of RA?	
7. Please give any data (or opinion) you may have to show whether the use of RA is (or is not) good in environmental terms. For example: <ul style="list-style-type: none"> • Is the energy used to produce RA more or less than that used to produce normal aggregates? • Are RA transported long distances? If so, how does this affect the environmental value of using them? • Is there any policy, or practice, to encourage the use of RA <u>simply in order to reduce waste</u>, even if the environmental impact may be worse? 	

Information (with differing degrees of detail) has been provided by Austria, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Russia, Slovakia, Sweden, Switzerland and UK.

Briefly, the information is as follows:

Austria

- use in concrete - less than 1% - limited availability;
- little RA used, mostly RCA from roads, recycled in new roads;
- usually coarse aggregate; occasionally fine, subject to third-party approval;
- limits on permitted exposure classes, depending on source of RA;
- five different types of RA, requirements generally same as for natural aggregates;
- greater energy requirement than virgin aggregates;
- not enough RCA available

Denmark

- use in concrete - never really taken up by the concrete industry, maybe for market/commercial reasons;
- it is established that there are no significant technical obstacles to recycling of aggregates;
- however, use of RA– most of the available C&DW is used for road construction, sub-base filling material, etc, so there is little available for concrete;
- recently renewed interest from the precast industry - would like to crush/recycle rejected elements and surplus production to re-use in their own production;
- since 2006 the Danish code for structural concrete (DS 411) has permitted the use of recycled aggregate in structural concrete, subject to certain limitations;
- after introduction of Eurocode 2 the subject is in the process of being included into the Danish application document to EN 1992-1-1;
- NAD for EN 206-1 in Denmark contains the following requirements regarding RA:
 - general suitability is established for RA of crushed concrete and masonry in compliance with EN 12620. Crushed concrete and masonry shall be sorted and meet the criteria for fine and coarse aggregates in EN 12620.
 - RA only allowed in least aggressive exposure classes;
 - RA are allowed in amounts up to 30 % of fine aggregates and 100 % of coarse aggregates.
- Eurocode 2 1992-1-1 and forthcoming NAD:
 - RA allowed in least severe exposure classes and only up to C30/37;
 - RA only allowed from clean source i.e. crushed structural concrete only;
 - Proportions of RA limited to 10 % (fine) and 20 % (coarse aggregate).

Finland

- use in concrete - less than < 1% (estimated). In precast, some very limited use of crushed rejected products, but in readymix, almost none
- basis of use is EN206 Annex E;
- no significant increase in use in concrete foreseen, natural aggregates remain economic;
- more than 80% of demolished concrete is recycled, used for road construction sub-bases etc.

France

- use in concrete - in less than 1% of all concrete; largely used in all-in unbound form in road construction;
- not allowed in civil engineering structures. Otherwise permitted, but the only significant use in concrete is for lean concrete for road and airport pavement.
- RA (fine, coarse, all-in) must comply with the French version of EN 12620+A1 *Aggregates for concrete*. Further, contracts may require conformity with standard XP P 18-545 *Aggregates*, particularly the NF quality mark is specified. As this is a new regulation, RA are little used in concrete.

- three permitted types of coarse aggregate with different percentages of (concrete + stone) content (at least 70%), together with limits on the content of other constituents;
- also requirements and test frequencies for sulfate content, density, shape, absorption etc;
- also limits on content of RA, depending on exposure;
- in some types of RA (and all recycled sand) limits on strength class;
- the content of RA must be classified as in EN 933-11 *test for the constituents of coarse recycled aggregate*;
- largely used in all-in unbound form in road bases;
- current study on this topic with French administration, aggregate producers and readymix industry to develop the use of this type of aggregate;
- future use and environmental impact of RA is very dependent on transport. Use more likely in regions like Paris where there are no natural aggregates.

Germany

- use in concrete production is not yet of practical relevance in Germany, in spite of law requiring that recycling should be the first choice;
- this is not a matter of missing regulations: guidelines and standards exist;
- permitted constituents: recycled hardened concrete, recycled mix consisting of recycled concrete and bricks;
- permitted types: coarse aggregate only, not fine;
- limitations on use include:
 - only allowed in certain exposure classes;
 - for use in wet conditions, the origin of any RA must be known to exclude the risk of ASR;
 - no differences in structural design, but the total amount of RA is limited: less is allowed in more aggressive exposure classes;
- 45% is the maximum permitted content;
- Disadvantages include:
 - no cost advantage to readymix producers;
 - technical problems - cement content; more admixtures needed; increased water demand; too many fines, without large amounts of water for washing;
 - same processing technology - crushing, sieving, washing etc, so no benefits in energy consumption;
 - problems of continuity and quality of supply.
- environmental advantages: reduced landfill and waste, reduced use of natural resources;
- an important research paper on recycling potential was circulated to TC104/SC1/TG19. Among other things it mentions the adverse environmental effect of the increased cement contents which may be required in concrete including RA, and the fact that the potential demand for recycled aggregate cannot be met by the available supply.

Ireland

- use in concrete - almost none, no demand, and no immediate change foreseen;
- use likely to continue to be as fill;
- suitability of coarse RA has not been established, but National Annex to EN 206 allows its use with "agreement of the parties involved on a project by project basis";
- all C&DW material other than organic material, steel and gypsum is permitted;
- requirements of E3 of Annex E EN 206 apply (limitations on physical and chemical properties);
- additional processing costs, and planning regulations;
- reliable sources on supply of RA is likely to be confined to large urban areas;
- the Irish industry has healthy deposits of excellent quality natural aggregates and sand.

Italy

- use in concrete - low, because of the requirements/limitations imposed by legislation and the idea that the quality of concrete is lower; coarse only is used; in 2011 only 11% of concrete producers had ever used RA. No data on volumes or percentages.
- C&DW permitted; a national technical regulation for construction establishes permissible strength classes of concrete and percentages of use of RA, based on their source (rubble, crushed concrete and reinforced concrete, reuse of concrete directly in the plant), also on fpc system in use by aggregate producer;
- use of RA expected to increase, because of restrictions on the exploitation of quarries and aggregate extraction from rivers;

Netherlands

- use in concrete - about 1.5% of aggregates used in the concrete industry as a whole are of recycled origin;
- the quantity of RA available is predicted to double, 2003 – 2025.
- there is a national guideline BRL 2506 on the use of RA, including use in concrete;
- aggregates classified by source:
 - concrete aggregates (90% concrete);
 - mixed aggregates (at least 50% concrete, plus masonry);
 - aggregates from masonry;
 - fine aggregates 0/x
 - sand from the crushing process.
- both coarse and fine aggregates are allowed;
- up to 30% by volume of coarse aggregate can be recycled concrete aggregate, and can be used without notice. Higher amounts can be used with agreement of client. If this higher amount is over 50% by volume, reconsideration of structural calculations is required.
- there is also a recommendation (not yet in force) to permit the use of recycled fine aggregate at levels up to 50%.

Norway

- use in concrete - currently very low, and not likely to increase significantly; mainly of crushed precast elements; future use is likely to continue to be overwhelmingly in road bases;
- environmental impact is large because of long transport distances in Norway;
- provisions for use of RA now included in National Annex to EN206.
- elements of the Annex:
 - both fine and coarse aggregates are permitted;
 - use of masonry and bricks is permitted;
 - RA is divided into two types Type AN and Type BN, with Type AN having more stringent regulations on mineral content, density and water absorption. However, *higher* percentages of Type AN are allowed.
 - use of fpc is required;
 - RA considered to pose a risk of asr, unless other evidence is available;
 - if there are requirements for water penetration, frost and chloride penetration, use of RA has to be documented and justified;
 - for recycled precast concrete products, a maximum of 5% coarse and fine is permitted without restriction;
 - content of RA restricted, dependent on strength class and exposure class – low levels (5 - 30%).

Russia

- use in concrete - 2-5% of concrete produced may contain RA;

- in practice only RCA used;
- only low classes of concrete permitted (C15-20).

Slovakia

- use in concrete - very low (< 0.05%);
- use mainly of coarse aggregates;
- only RCA used;
- no limits, other than requirements of EN206.

Sweden

- use in concrete - likely to increase when the new national standard is implemented and the focus on RA increases, and when there are clear rules and incentives;
- revised national application standard to EN 206 will be published in Sweden very soon; in it the new rules for RA follows to large extent the recommendations given in EN 206 (Annex E).
- two classes of RA, exposure considerations determine which of the two classes may be used;
- coarse aggregate only allowed;
- there are specific quality requirements related to the crushing process;
- special considerations for structural design (e.g. assumed reduction of E-modulus).

Switzerland

- use in concrete - estimated at 10%; eco-labels impose pressure to increase use, but no great increase expected as level of recycling is already 85%, and no reliable sources in non-urban areas;
- use follows requirements of EN12620 and National Annex, which applies equally to virgin and recycled aggregates; only coarse aggregates used;
- limitations on use based on exposure classes;
- sustainability issues have been taken seriously, and studies shown that use of RA in concrete is not significantly beneficial ... increased cement content, for example; on the other hand there is a serious waste disposal problem, and restrictions on aggregate extraction, so recycling generally is practically and politically necessary.

Turkey

- no use in concrete yet;
- no restrictions other than rules in EN206 and EN12620;
- virgin aggregates always cheaper, but cost differential is becoming smaller;
- government policy to use recycled aggregates, but no formal endorsement or requirement.

UK

- use in concrete - estimated 0.01%; significant increase not foreseen, not least because of inconsistent supply;
- assessment schemes (e.g. BREEAM) measure resource use by mass, but RA is not classed as 'resource use' and there is some pressure from specifiers to use it in concrete even though not necessarily true that use of RA reduces the environmental impact of concrete -
 - energy requirement is higher;
 - more expensive;
 - risk of contamination;
 - more cement;
 - road material is better use for recycled aggregate.
- only coarse aggregate is used, subject to limitations set out in NAD -
 - content - of fines, sulfates, lightweight material etc;
 - content of coarse RCA in concrete;

- physical and chemical properties;
- strength and exposure classes.

USA

- both coarse and fine allowed in building construction if meet ASTM specification requirements, which can be difficult. In highways, restrictions on use being lifted.
- other materials which have been accepted: slag, crushed glass, recycled asphalt, foundry sand, recycled rubber tyres;
- no specific restrictions on use, or grades of concrete in national standards; regional standards permit RA;
- <2% estimate of concrete containing RA;
- for economic reasons (e.g. transport costs and energy costs in processing) future use not likely to increase. Also codes and specifications do not explicitly permit use of RA. However, questions of waste and landfill are becoming more important

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