Application of construction and demolition waste

Ch.F. Hendriks, Mrs. G.M.T. Janssen
Delft University of Technology, Faculty of Civil Engineering and Geosciences
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1. Introduction

Construction and Demolition Waste (CDW) is produced during all stages in the life cycle of a building. Many types of CDW can be reused [1]. The options for reuse will be discussed in this article. Unless otherwise stated, all percentages quoted refer to percentages by weight.

2. Concrete rubble

Without any processing, concrete rubble can be used for:

1. hard standing;
2. bank protection;
3. fill and raising areas;
4. road construction;
5. noise barriers and embankments.

Most of the concrete rubble aggregate is sold as a 0/40 (0-40 mm grain size) fraction for road subbases. Concrete rubble delivered to a recycling plant should contain no more than 10% of wood by volume. Hence, prior to or during processing the wood has to be removed from the concrete rubble, either by mechanical sorting, pyrolysis or using screening techniques (e.g. water baths). If the processing plant incorporates a water bath then up to 30% (by volume) of wood may be contained in the waste. The waste should not contain any plaster, anhydrite, porous insulating bricks or aerated concrete. These materials are too soft and adversely affect the strength when used in the application described below. Plaster and anhydrite can also expand due to water absorption. When anhydrite screeds are poured they can be separated from the concrete floor by pouring them on a plastic film.
Other types of contamination which adversely affect the quality of the aggregate include soil (clay agglomerations), aluminium (foaming), products containing tar, glass, chloride, plastics (polystyrene) and materials leading to alkali-aggregate reactions.
Contamination may lead to expansion or staining (iron and vanadium compounds).

After removal of contaminants through selective demolition, screening and/or air separation and size reduction in a crusher to aggregate sizes (generally 0/40 mm), concrete rubble can be used as:

- Aggregate in asphaltic concrete: Crushed concrete rubble is particularly suitable for this application. It should not contain any wood and more than 1.5% SO_3 (as gypsum);
- Road subbases;
- Concrete containing secondary concrete aggregates.

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After washing, recycled concrete aggregates may be used as a replacement for gravel in concrete. This is the highest level application of secondary aggregate. The 0/4 fraction has strong hydraulic properties, as a result of which concrete containing this fraction sets too quickly. Hence, it is better to use the 4/32 fraction or to mix the 0/4 fraction or to mix the 0/4 fraction with natural sand. In 1997 only 3-4% of all crushed stony CDW waste was used in concrete as a replacement of its natural equivalent in the Netherlands [1].

The strength of concrete in which all the gravel is replaced by secondary aggregate is generally 80 to 100% of the strength of concrete made with natural aggregates. A disadvantage of concrete containing secondary aggregate is that its density is less, and as a result its porosity is higher. Hence, more water has to be used to ensure full saturation of the aggregate with water and the concrete may require a more intensive compaction.

According to the current specifications, crushed concrete aggregate used for the production of new concrete should contain at least 80% crushed concrete with a density greater than 2100 kg/m^3. It should contain at most 10% of the other types of stony material and at most 5% asphalt. The concrete rubble should contain no more than 1% of plaster [2].

For concrete of higher grades the secondary aggregate should contain at least 95% crushed concrete. Crushed concrete aggregate with a density greater than 2100 kg/m^3 can be used for all types of concrete. Only a little more cement is needed than when gravel is used.

High level application of crushed rubble aggregate may require the removal of plaster from walls. The first screening operation before the crusher removes plaster and soil to a sufficient extent.

The application of crushed rubble aggregate depends on its mechanical properties. The quality of the material has to be monitored to prevent structural damage.

The deformation properties of concrete made with secondary aggregate are less favourable than those of concrete made with gravel. There are two potential solutions to this problem:

Substitute 100% of the gravel by secondary aggregate and increase the dimensions of the structure by 10%.

Substitution of 20% of natural aggregates by mixed recycled aggregates does not reduce the quality of the concrete with a strength up to 65 MPa. Because of its lower density the use of secondary aggregate may require thicker walls between dwellings as concrete made using secondary aggregate is less denser (by about 30 kg/m^3) than concrete made with gravel (2500 kg/m^3).

The higher porosity results in greater water absorption which may increase the expansion and shrinkage of the concrete. As a result of the greater water absorption concrete containing secondary aggregate cannot be used outdoors.

The crusher plants have to be funded by amounts charged to demolition contractor for processing CDW and the secondary aggregate sales revenue. Secondary aggregate for road subbases is cheaper than natural products, but secondary aggregate for making concrete is more expensive.

Gravel has traditionally been used in concrete and there is some reluctance against the use of secondary aggregate which is more angular. However, crushed limestone and other types of crushed stone are increasingly being used and these materials are also angular. To encourage the use of secondary aggregate to replace gravel in concrete the price of the secondary aggregate has to be reduced and its use should be required in specifications, otherwise gravel will be used. Another option to encourage the use of secondary aggregate in concrete would be to ban the landfilling of CDW completely. This has been the case in the Netherlands since 1997, and results indicate that this policy is very effective, provided a proper control system is available.

The demand for recycled aggregates for road construction in the Netherlands currently still exceeds supply. In 1997, 99% of all reused rubble was used in road construction, primarily in road subbases. However, rubble is faced with increasing competition from other wastes. Hence a shift in the use of secondary aggregate as a replacement for gravel in concrete would be desirable. Reported problems with this application are listed below.

- It is difficult to meet the quality requirements for concrete related to contaminants.
- Costs are increased by additional quality control, secondary aggregate storage, and modification of the production process or concrete composition.
- Costs of transport from the demolition site to the crushing plant and then to the building site.
- The perception that secondary aggregate is waste.

The fraction smaller than 4 mm has to be screened out in view of its effect on the required quantities of water and cement. This fraction, crusher fines, can be used in road construction, instead of sand. The quality, in environmental terms, of crusher fines often poses problems. This material may be contaminated with PAH, SO_4^{2-}, antimony (Sb), mineral oil and occasionally lead and zinc.

Technical requirements for use in concrete

In comparison with gravel, recycled aggregates have different properties. One has to consider these properties when composing concrete mixes and when processing concrete mortar. As a consequence, the old Code NEN 5905 (1988): 'Aggregates for concrete, sand and gravel' was recently replaced by NEN 5905 (1997): 'Aggregates for concrete'[3]. Materials with a bulk density of at least 2000 kg/m^3'. For the use of recycled concrete aggregates and recycled masonry aggregates, the Revised Version includes CUR Recommendation 4: 'Recycled concrete aggregates as an aggregate for concrete' [4]; and CUR Recommendation 5: 'Recycled masonry aggregates as an aggregate for concrete' [5] respectively. The limit values for contamination are based on various strength and durability aspects, such as.

- retarding influence on cement hardening;
- corrosion of reinforcement (chlorides);
- swelling under influence of moisture absorption (e.g. pieces of wood);
- formation of ettringite (swelling caused by e.g., residues of gypsum);
- alkali-silica reactivity (e.g. broken pieces of Pyrex glass);
- decrease of compressive strength (e.g. contaminants of asphalt).

In Table 1, a summary is presented of the most important requirements applicable to aggregates used in concrete according to NEN 5905 [2].

Table 1. Summary of the most important requirements applicable to aggregates used in concrete according to NEN 5905 [2]

Variable	Unit	Requirement	Method of determination
Grading		comparable to natural aggregate	NEN 5916
Particle shape		critical shape recommended	
Flat pieces	m/m by mass	< 40%	NEN 5935
Aggregate with round surface		limited percentage for use in concrete for roads and pavements	NEN 6240
Shell content	m/m (by mass)	percentage carbonates < 10% in coarse aggregates percentage carbonates < 25% in fine aggregates	NEN 5922
Very fine material	m/m (by mass)	grade 0-1 mm: < 10% grade 0-2 and 0-4 mm: < 4.0% coarse : < 3.0%	NEN 5917
Physical properties and requirements			
Composition of aggregate	m/m (by mass)	recycled concrete aggregate: concrete content > 90%, LA-value < 40 recycled mixed aggregates: concrete content > 50%, LA value < 50 bitumen, rubber, metals, glass, etc. < 1.0%	NEN-EN 1079-2/visual
Other non-stony elements	V/V (by volume)	bitumen, rubber, metals, glass, etc. < 1.0%	NEN 5942
Chemical requirements			
Chlorides	m/m (by mass)	grades 0-4 mm > 4 mm non reinforced: < 1.0% < 1.0% reinforced: < 0.1% < 0.05% prestressed: < 0.03% < 0.015%	NEN 5921
Sulphates	m/m (by mass)	< 1.0%	NEN 5930
Total sulphur compounds	m/m (by mass)	< 1.0% < 2% if dry aggregate consists of slag	NEN 5936
Spot causing iron and vanadiu m compounds	-	index may not exceed 20	NEN 5923
Fine organic material	-	discoloration no darker than standard picture A, or not satisfy standard picture B	NEN 5919 NEN 5920
Soft components	m/m (by mass)	< 0.5%	NEN 5918
light material	m/m (by mass)	< 0.1%	NEN 5933

m/m this is the standard unit in 'Dutch'
(by mass) this is the standard unit in 'English'
V/V this is the standard unit in 'Dutch'
(by volume) this is the standard unit in 'English'

3 Wood

Most of this wood is landfilled or incinerated as a by-product in either coal power plants or cement kilns. Prior to incineration the wood will have to be reduced in size drastically, with e.g. cryogenic methods. In table 2, an overview of wood processing techniques is provided.
Undamaged wood can be reused as it is demolished.

In other cases, wood may be:

- planed, reduced in size;
- processed to paper and cardboard;
- processed to board products such as clipboard (standard or cementitious).

The processing options are not available for board products, chipboards, plastic coated wood and impregnated (pressure treated) wood. Painted wood can generally be processed without problems. During milling, the paint is separated in the form of particles and extracted. Alternatively, wood can be incinerated or decomposed by gasification or pyrolysis. After hydrolysis of the pyrolysis, they can be used in chemicals production.

Wood can also be fired in coal-fired power stations if dedicated wood burners are installed. For this application the wood has to be finely ground to ensure complete combustion. There are plants to fire approximately 10% wood in the Netherlands.

The main problem in processing wood wastes is the lack of sales opportunities for processed wood. Board manufactures can already obtain sufficient supplies from other, cleaner, sources. Furthermore, the chipboard industry in Germany is now required to take back used boards and recycled them. Gasification and pyrolysis are not being implemented, as these methods are too expensive.

Table 2. Processes for the reuse of waste wood			
Processes for the reuse of waste wood			
Process	**Type of waste wood**		
	Clean, unprocessed	Slightly contaminated	Pressuretreated or glued
Finger jointing Finger jointing is used to splice waste stock to usable lengths. Planks, beams and sheet may be produced. The adhesives used do not pose any environmental problems when the material is recycled.	X		
Pulping Wood waste is subjected to thermomechanical processing to produce wood pulp for papermaking. Only clean wood, as chips or fine dust can be used.	X		
Composting Waste wood is reduced in size, mixed with sludge and soil and an organic fertiliser is then formed by bacterial action. This process is particularly suitable for wood residues	X		
Substrate production Wood wastes are cut into thin strands to produce peat substrate mats used as a growth medium in greenhouses or for blending with potting compost. This process requires clean wood wastes, although dipped and brushed treatments are acceptable. Substrate mats are fully recyclable.	X	X	
Moulding Wood wastes are mixed with binders and compressed in moulds to produce boards and other products. Organic binders can be used to manufacture products from waste wood such as demolition wastes. Products include wall panels, work surface, window frames, table tops, etc. Wood strands can be moulded with cement to produce boards.	X	X	
Chipping for roof tile production Wood chips are mixed with magnesium oxide and ammonium polyphosphate to produce roof tiles. All types of wood, apart from boards and pressure-treated wood can be used.	X	X	
Chipping for chipboard production Wood chips are bonded to chipboard sheets. In view of the strict quality requirements this is generally limited to clean wood wastes. Clean construction and demolition wastes and wooden packaging can be processed. When the resulting chipboard op pallet blocks are incinerated NOx is produced.	X	X	X
Pyrolysis Carbonaceous materials are heated in the absence of oxygen to produce solid, liquid and gaseous fuels such as charcoal.	X	X	
Gasification Gasification converts old wood in a flammable, low caloric gas, which can be used as a fuel. Gasification of wood waste is attractive because pollution like nails, paint etc. is no problem.	X	X	X

4. Asphalt rubble

Asphalt waste can be effectively reused in road construction, either hot or cold. Transport should be minimised when recycling asphalt.

Part of asphalt waste can be reused by means of hot processing while another part can be reused cold, in road subbases. For cold recycling the material is used on its own for roads subjected to light loads and mixed with cement for more demanding applications. High proportions (95%) of material can be reused in hot processing. However, a disadvantage of hot reprocessing is that PAH is released from the tar contained in the material. For cold recycling the asphalt rubble is reduced in size, and a regeneration agent is added.

The remaining broken asphalt can be bonded with cement and used in place of sand/cement sub-bases.

Only a limited proportion of asphalt can be reused in highly pervious road surface, as the composition of these mixtures is highly critical

5. Metals

Metals have to be sorted first as they greatly increase revenues. Preferably, steel should be reused directly. If it is unsuitable for direct reuse it is melted to produce new steel.

6. Glass

Glass in an alkaline medium can react with the alkali's. Glass in concrete can cause damage to the concrete from alkali-slica reaction. This is the reason why only a small amount < 1% (together with non-stony materials) may be allowed in recycled concrete aggregate (RCA)
Is it very difficult to keep glass intact when buildings are demolished in their entirety. The presence of glass in secondary aggregate used for concrete or asphalt production may reduce the durability of the resulting material. Window frames with glass in them can be removed to keep the glass and wood out of the rubble. Alternatively, the glass may be cut from the frames. If clear glass can be collected without contamination it can be recycled to new clear glass.

Options to deal with contamination:

- Provisional approach: application under controlled circumstances;
- Selective demolition of chimneys, asbestos bituminous roofing and gypsum products;
- Cleaning.

7. Masonry waste (including calcium silicate bricks, ceramics and stone)

On the whole, the potential applications and problems associated with masonry rubble are the same as those of concrete rubble. However, there are some differences, listed below.

- Aggregate for asphalt concrete
  - Masonry rubble cannot be used as aggregate for asphalt as its porosity is too high and as it has insufficient crushing resistance.

- Road subbase
  - Due to its low crushing resistance masonry rubble is less suitable for use in road subbases.
- Aggregate for concrete
  - Masonry rubble can be used for concrete up to grade $B_{22,5}$. The strength of the resulting concrete is 65 to 90% of that of concrete containing natural gravel. The tensile strength and modulus of elasticity are also reduced somewhat, while its creep is increased, and shrinkage is 10 to 65% higher than in gravel concrete.
  - If a higher concrete quality is required then the adverse impact on the concrete quality can be offset by increasing the cement content by 20 - 40 kg per m^3.

A special application of recycled masonry aggregates is to use it as thermally insulating concrete containing polystyrene beads. This is a lightweight type of concrete with higher thermal insulation.

A potential special application for recycled masonry aggregate is to use it as aggregate in traditional clay bricks as well as in calcium silicate bricks (currently being investigated).

- The 0/4 fraction is used as a replacement for clay in bricks and as a sand replacement in calcium silicate bricks.
- For use in bricks this fraction should not contain any lime to prevent adverse effects on strength, shrinkage during firing, durability (swelling) and colour.
- When used in calcium silicate bricks this fraction may contain lime. Calcium silicate bricks are produced at a pressure of 15 bar, at lower temperatures than clay bricks.

When the 0/4 fraction is used adhering cement has to be removed by a mechanical (grinding or brushing) or thermal process. Interfacial stress is created when cement covered bricks are heated to 900 °C and the cement can then be removed as fines. This material can be heated to produce clinker. The volume of CO_2 produced by this process is lower than that when natural materials are used. Lime mortar can be reused after heating. When processing sodium silicate bricks any adhesive material has to be removed mechanically.

8. Soil

Any soil included in CDW is soil clinging to demolition wastes and wastes collected in skips (dumpsters, waste containers). The presence of soil makes CDW less suitable for processing in crusher plants as it amounts to additional ballast. Large quantities of soil may lead to refusal to accept the batch. This problem can be avoided by taking care to prevent excessive amounts of soil sticking to the wastes.

9. Paper and cardboard

Paper and cardboard can only be recycled and sold as waste paper if they are very carefully separated and collected. Residual material is landfilled or incinerated.

10. Insulation materials

The most common insulation materials are minimal wool (rock wool), glass wool, polystyrene (PS) and polyurethane (PUR). Due to their adverse impact on strength, all insulation materials reduce the reprocessing options for CDW. It is therefore advisable to dispose of insulation materials separately. PUR foam placed in-situ poses a problem as it bonds strongly to other materials.

Mineral wool

Blankets and bats (boards) fixed by cavity anchors should be removed and may be reused if they are intact. Mineral wool may be reused as soil conditioner after size reduction. This is a form of landfilling. These recycling processes were developed for mineral wool used in greenhouse horticulture (hydroponics) and are still in the experimental stages. Used mineral wool can be converted to granules by size reduction and screening. These granules may be used to produce new mineral wool products. Mineral wool used in greenhouse horticulture is taken back and reused by Grodan/Rockwool and Gultilene/Isover.

Glass wool

Some producers use 50% cullet (broken glass) in glass wool production. These companies have developed a process for recycling glass wool. First, organic materials and the binder are gasified in an oxygen-free environment (nitrogen). The fibres are then used to produce new glass wool. Glass wool reduced in size cannot be used for soil improvement or as aggregate. Adhesion to it is poor and its expansion may fracture concrete. It may be possible to use size-reduced glass wool in the production of new glass wool, however, there is no information available about this.

PUR foam

Intact PUR foam boards may be reused. If PUR foam is landfilled, isocyanates may be leached from it. If PUR foam were selected despite these environmental disadvantages it would be best to use water-based PUR blow with CO_2.

Expanded PS foam

PS boards not damaged in the demolition operations may be reused. Ground PS boards can be reused as a soil conditioner, unless the PS in hydraulic (water-repellent). PS is a thermoplastic material and may therefore be softened for the production of new material, however this process is not used at present. The beads of expanded PS foam can be separated for the production of new boards, again this process is not yet used.

UF foam

Urea formaldehyde (UF) was primarily used for cavity insulation in existing buildings. It bonds to one cavity leaf and shrink away from the other leaf. UF foam cannot be reused.

Perlite

Perlite is produced from volcanic rock consisting of silicon oxide (S_iO_2) and aluminium oxide (Al_2O_3). Loose perlite granules can be reused without further preparation.

11. Garden wastes

Construction and refurbishment project garden waste may generally be composted successfully, provided it does not contain too much pollution of non-biodegradable materials.

12. Dangerous wastes

The construction of every new house produces about 10 kg (traditional dwellings) to about 20 kg (large dwellings) small-scale chemical or hazardous wastes. Dangerous wastes should always be separated from other wastes in CDW. The presence of any dangerous wastes in CDW will mean that the full batch of CDW is unsuitable for reuse and will be classified as dangerous waste in its entirety. Hence, dangerous wastes have to be separated by type or kept separate, and may only be transported and processed by reputable companies. Any asbestos removal operation has to be carried out by specialist companies.

Four types of dangerous waste may be recycled:

1. waste oil: used as fuel with or without further processing, or refined to produce new oil;
2. paint and solvent wastes: recovered by distillation or used in primer production;
3. blasting abrasives: may be reused after cleaning (it would be better to use CO_2)
4. batteries and storage batteries (rechargeable batteries).

Other types of dangerous waste have to be incinerated or landfilled. Notification forms, to inform the authorities, have to be completed for dangerous wastes.

13. Asbestos

Asbestos fibres (all varieties) are nowadays considered to be carcinogenic and their use has therefore been banned in most EU countries. Asbestos boards have to be removed, disposed of and processed most carefully, by specialist contractors. Only loose asbestos fibres are carcinogenic. Hence personnel working in asbestos board plants and operatives cutting or drilling asbestos products are at a greater risk of cancer than those working elsewhere in the asbestos production on industry. However, as long as the boards are not drilled into no fibres will be released and the asbestos will not pose any health hazard. The release of fibres can largely be prevented if the asbestos boards are removed in their entirety and disposed off by a certified disposal company. All waste asbestos is landfilled.

14. Plastics wastes

Four percent of all crude oil processed in Europe is used for manufacture of plastics, particularly PE (polyethylene, polythene) and PP (polypropylene). 20% to 26% of the plastics production is used in the construction industry while 40% is used by packaging industry.

In 1998, 300,000 tonnes of plastics were used in the construction industry. 50,000 tonnes were used for maintenance, repair and refurbishment, and 200,000 tonnes for residential and non-residential new buildings. The 300,000 tonnes included 120,000 tonnes of PVC, 30,000 tonnes of which was used for PVC pipes. Other plastics commonly used in the constructions industry include PE (polyethylene, mostly used in packaging and vapour-check films), and PS (polystyrene, mostly used for insulation). These three plastics are all thermoplastics that can be recycled.

Thermosetting plastics such as PUR (420,000 m^3), polyester and formaldehyde resins are difficult to reprocess. The main applications of plastics in ordinary homes are listed in table 3.

Table 3. Primarily applications of plastics in conventional housing		
Component	**Material**	**Av. Quantity per house in kg**
Common applications:		
Seals	Rubber, PVC	3
Glazing profiles	PVC	20
Formwork/shuttering	PS/PVC/PE	2
Fasteners	Formaldehyde	3
Interior walls	PS granules	3
Pipes and fittings	PVC/PE/PP	15
Roof finishing	PVC/PP/PE	15
Gutters	PVC	10
Rooflights	PC, acrylate	4
Roof (prefabricated), insulation	PS/PUR	6
Electrical installation	PVC, etc.	10
Films and slabs	PVC/PPE	5
Curtain tracks	PVC?	6
Frames, interior doors	PVC	25
Caulk, sealants	Acrylate, PU, etc.	1
Transparent components	PC/acrylate	?
Adhesives	Some 10 thermosetting plastics	
	PVC	1
Wall finishes (theresholds and coping)	PVC	4
Sanitary wares	PE	4
Chimney fittings	PVC/polyester	3
Hoses	Wide range	1
Paints and coatings	PS	5
Floor insulations	PUR/PS	10
Wall insulations	?	8
Sunshades		
Potential applications:		
Glazing	PC/acrylates	?
Dormer windows	Polyester (gfr),etc.	50
Doors	PVC/PS/PUR	60
Facade cladding	PVC/melamine	30
Facade components	PVC/PS/PUR	30
Rooflights	Polyester	20
Rooflights edges	ditto	15
Skirting boards	PVC	10
Drains	PE/PVC	8
Tiles	PUR/styrene-butadiene/polysulphide	20
Roller shutters	PVC	40
Central heating	PE/PP	30

**gfr: glass fibre reinforced*

Composition of plastics wastes

Plastic make up about 0.5% by volume of CDW arising in the construction industry.

- Part of this, mostly cable and pipe wastes, is produced by civil engineering projects and earthworks.
- Another part is generated by demolition operations and the proportion of plastic in demolition wastes is expected to rise rapidly due to the great increase in the use of plastics in the building industry in the sixties.
- Other plastic wastes arise from construction operations (approx. 1% by volume).

Some of the plastic wastes are short cycle materials: packaging materials, primarily PE/LDPE and PVC discarded during construction operations. Reducing and standardising packaging can reduce the volume of packaging in CDW. The remainder amounts to approximately 60 to 65 kg per house: primarily long cycle cutting losses. A large proportion of plastic wastes is of the long cycle type. The volume of long cycle plastic wastes is expected to increase. In table 4, an overview of the composition of plastic wastes in the Netherlands is provided.

Table 4. Composition of plastic wastes in the Netherlands

	[%]
PE&PP	30
PVC	40
PS	10
PUR	10
Other	10

Plastics waste recycling

In general, plastic wastes are not reused but landfilled or incinerated. The reuse of thermoplastic materials is economically feasible if the volume exceeds 200 tonnes of plastics in a region. This material has to be delivered separately. Clean plastic wastes are granulated and used to produce new plastic products.

High level reuse of PE, PP, PS, PVC, etc. is possible if these materials are collected separately and if they are clean. The applications become lower level as plastic wastes are mixed with other plastics or contaminants. The scope for high level recycling is limited due to the deterioration in properties. Virgin (new) material always has to be added for recycling.

Mixed plastics can only be recycled a few times, after which they have to be landfilled or incinerated. The properties of recycled mixed plastics are very marginal. This is one of the reasons why recovered mixed granules have a poor image. Potential solutions include standardisation in the selection of materials and the introduction of a requirement to keep plastic wastes separate.

In general, only 3% of plastic is recycled. One of the reasons for this is that recycling is difficult and expensive. For basic plastics in particular, virgin material is generally cheaper than recycled material. This applies in particular to PE, PP, PS and PVC packaging. Furthermore, the quality of the material is affected as recycled plastics always contain 1 to 2% contamination.

85% by weight of pipes and conduit (for electrical wiring) in the construction industry is made of PVC. Since the 1950s, million tonnes of PVC piping have been installed underground. The life of the pipes is 75 - 100 years. At present part of pipes are recovered annually. Due to unfamiliarity with the recycling system, only a smart part is recycled every year. PVC facade components have life of 50 years and, like pipes, they can be recycled up to 7 times. There have been recycling facilities for PVC window frames since 1992.

The recycling material is used for the production of new plastic profiles containing 70% recycled material, which has insufficient UV-resistance. Hence, the recycled material is co-extruded with 30% virgin material on the surface of the product. In future it may be possible to improve this ratio to 80-20 or even 90-10.

The recycling of transparent PVC roofing panels started in 1992. Due to contamination and the reinforcement, the recycling material has a poorer quality than new roofing elements and can therefore only be used for the lower face. The panels are converted to powder by cryogenic (low temperature) milling. The powder is then mixed with plasticizers and other materials for the production of new panels.

Recycling of mixed plastics wastes

Since 1995 the German authorities have required the recycling of 80% of plastics wastes. As this extends to mixed domestic plastics wastes this percentage cannot be reached using the methods described above. Hence, there was a need for a method to process mixed to process mixed plastic wastes, which may or may not have been collected separately from other wastes.

The following processing methods are available:

1. Incineration with energy recovery
   All types of plastic wastes can be incinerated in waste incinerators. Plastic wastes can be processed together with other wastes; there is no need for separating them.
2. Feedstock recycling
   Plastic wastes are converted to synthetic crude oil and gas with a high energy content. This process can be used for most types of plastic wastes. However, the plastic wastes have to be separated from other wastes, especially inorganic wastes.
3. Mechanical processing
   Plastic wastes separated at source or at a later stage can be milled to produce granulate and then used in the production of new products.

The major problem impeding feedstock recycling and mechanical processing is contamination of the plastic, particularly with the following materials:

- residues of the products contained in the packaging;
- adhesives, PUR, bitumen;
- glued joints;
- cadmium in pre- 1990 PVC window frames;
- fire retardant.

Environmental balance of plastics

An environmental balance of plastics includes all environmental impacts throughout the processing cycle:

- collection
- separation and initial processing to size-reduce plastic wastes to granules (the environmental impact of this stage is very low);
- processing;

- logistics (transport and handling);
- avoided production: the environmental impact of the avoided production processes.

It is assumed that the collected plastic wastes are processed in full and that all the above stages are included. The debit (cost) side of the environmental balance sheet lists all environmental impacts. The credit (benefit) side lists the avoided environmental impacts (energy and raw materials). The life cycle deficit is shown at the bottom of the balance sheet.

Concluding remarks

The Dutch approach to application of CDW has led to very positive results. Road and Concrete constructions with CDW meet all specifications without higher maintenance. The Netherlands play a leading role in Europe in this field. The Dutch results are applied in the CEN procedures for specifications for the technical aspects. Until now the environmental specifications do differ largely form one country to another. The Dutch approach has led to higher amounts but also to the assurance of a quality without risks for environment and health.

Literature

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