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POSSIBILITIES OF INCREASING THE USE OF RECYCLATES IN CIVIL CONSTRUCTION

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1. Production and management of C&DW in Czech Republic

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2. Possibilities of using concrete and brick recyclates for concrete production

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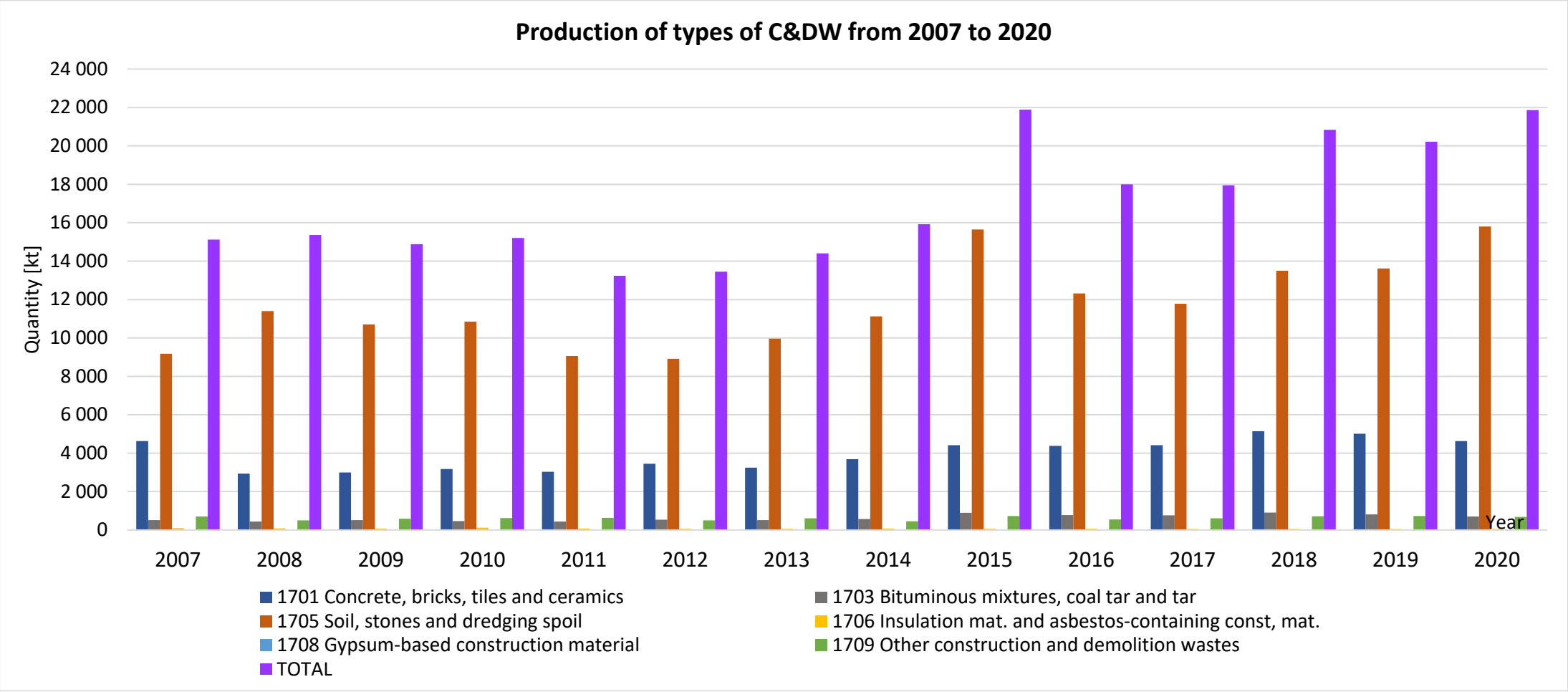
Production and management of C&DW in Czech Republic

This part of the presentation is focused on recycling of inert mineral waste - especially to these groups of materials:

- concrete and concrete structures,
- bricks and brickwork,
- mixtures of concrete, bricks, tiles and ceramic products that do not contain hazardous substances,
- soil, stones and dredging spoil, that do not contain hazardous substances.

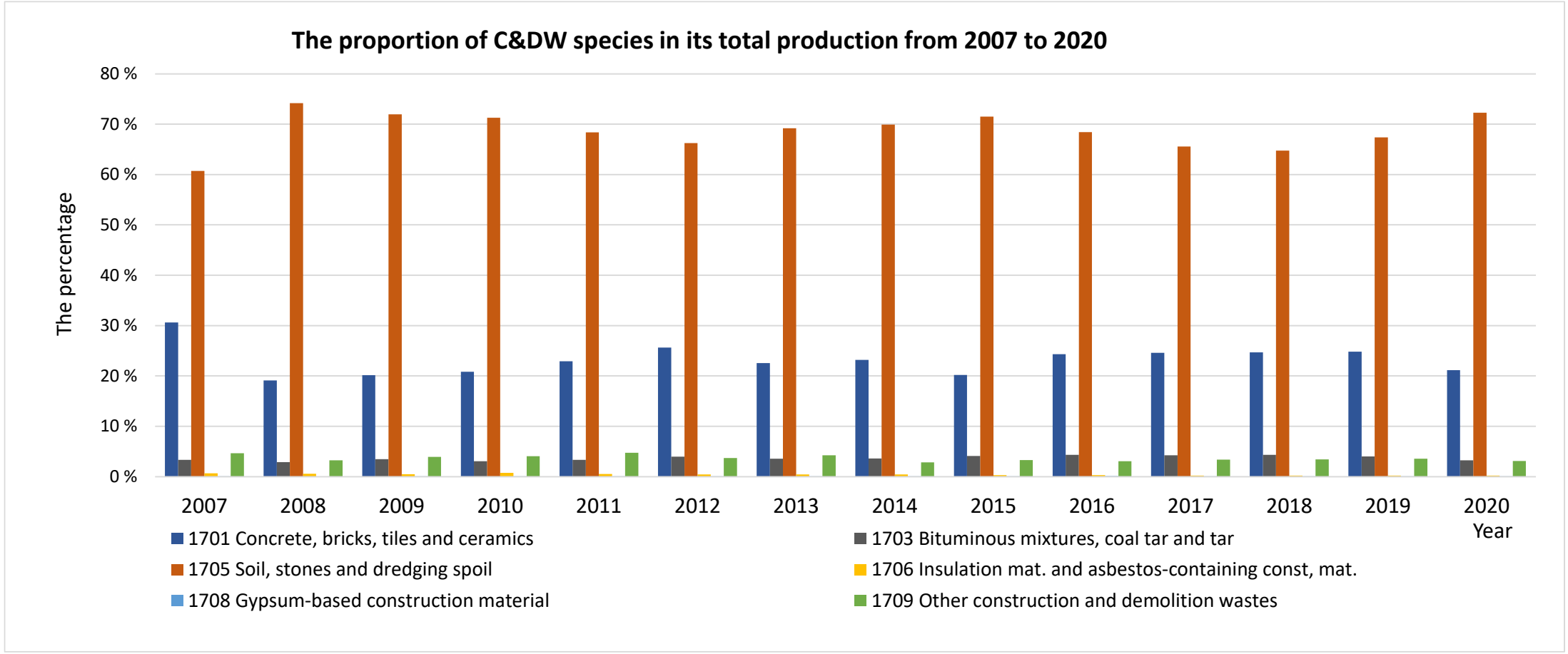
These components are a completely dominant part of C&DW production in the Czech Republic

Production and management of C&DW in CZ

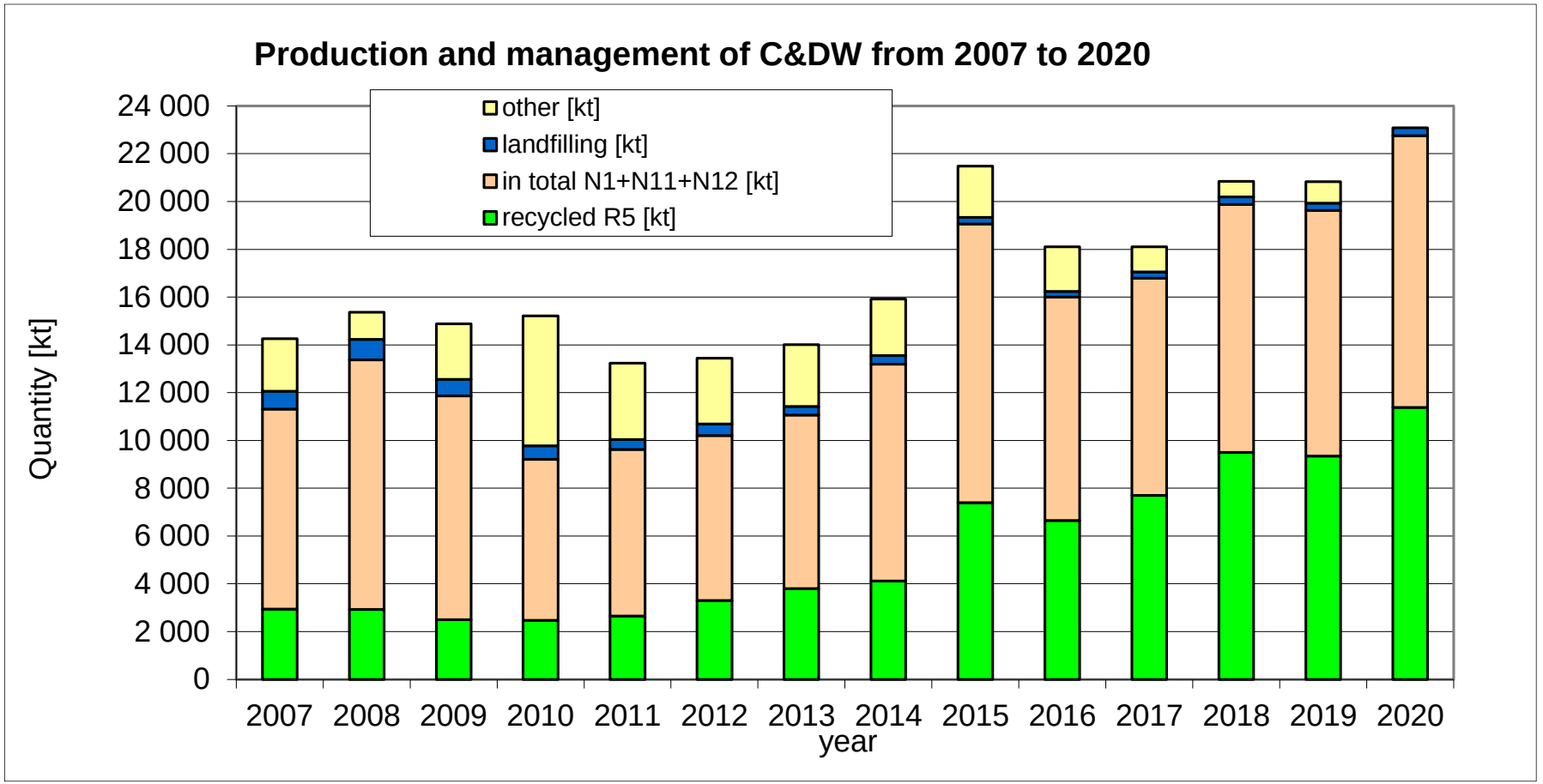


Production of the main types C&DW in the years 2007 to 2020

Production and management of C&DW in CZ



Production and management of C&DW in CZ



Production and management of C&DW from 2007 to 2020

Code C&DW 1701 - Concrete, bricks, tiles and ceramics

- Typical mineral waste, which is primarily intended for recycling and reuse of recycled materials in the building industry,
- in terms of strength - the most advantageous material is concrete - it should be stored separately during the deconstruction of buildings,
- the use of these materials after recycling is most often for backfills, underfills and for strengthening temporary roads on construction sites,
- use as a filler in concrete production is minimal,
- possible use of the fine fraction < 0.125 mm as a partial replacement of the binder as active admixture II (according to ČSN EN 206+A2),
- recycled bricks has especially great potential as a concrete filler.

Code C&DW 1701 - Concrete, bricks, tiles and ceramics

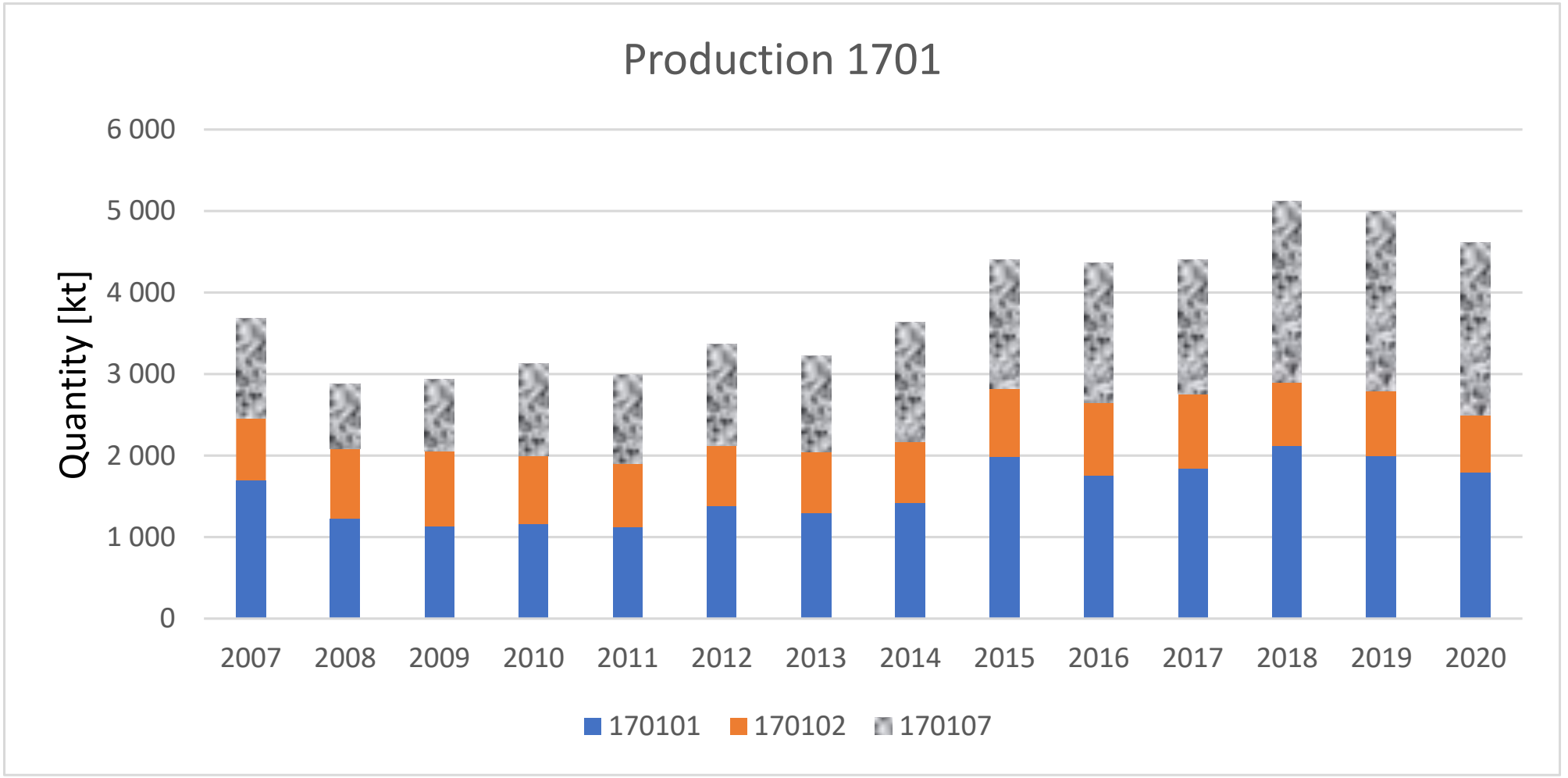
recycled bricks 2-8

recycled concrete 0 – 32

recycled concrete 32 – 63

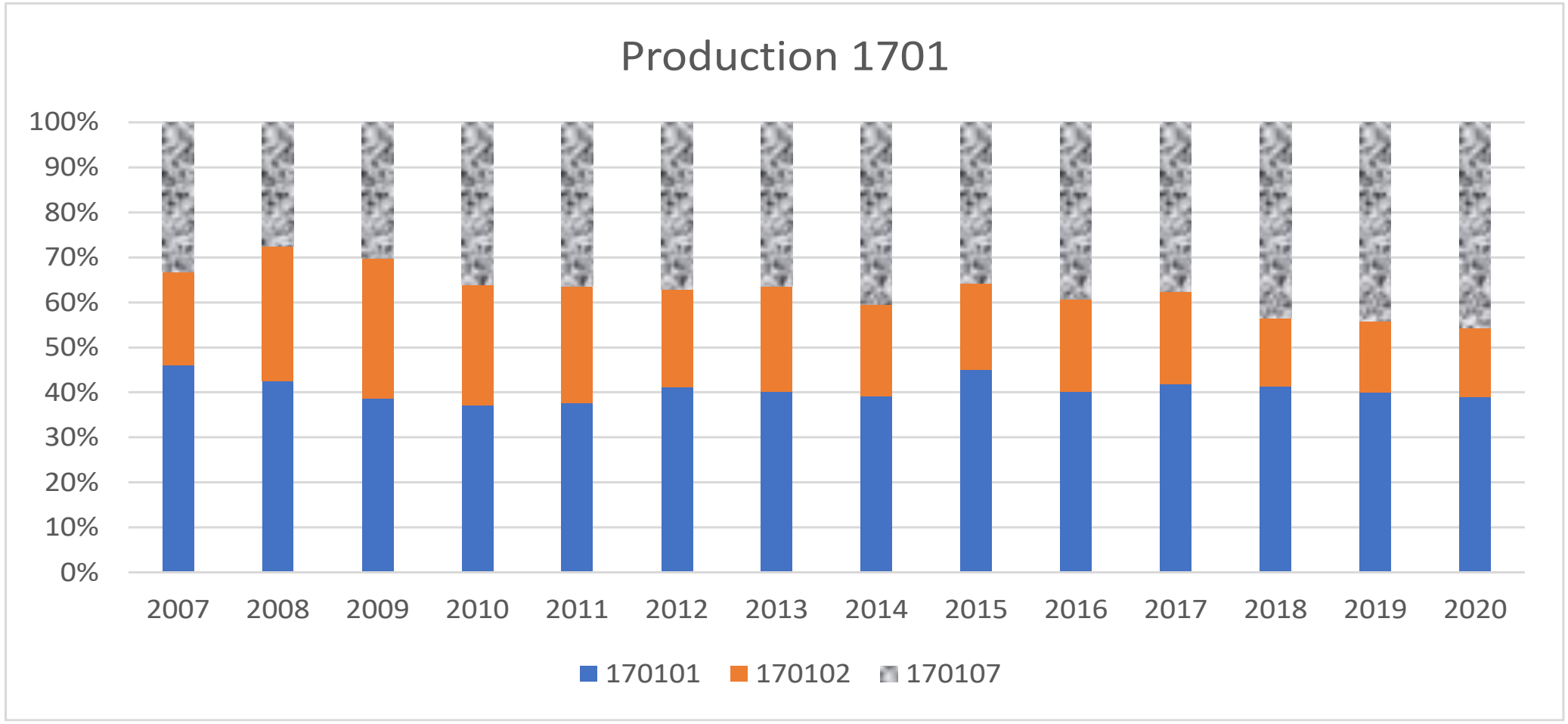
mixture of recycled concrete and bricks 0- 32

Code C&DW 1701 - Concrete, bricks, tiles and ceramics



Production of the main kinds of waste code 1701

Code C&DW 1701 - Concrete, bricks, tiles and ceramics

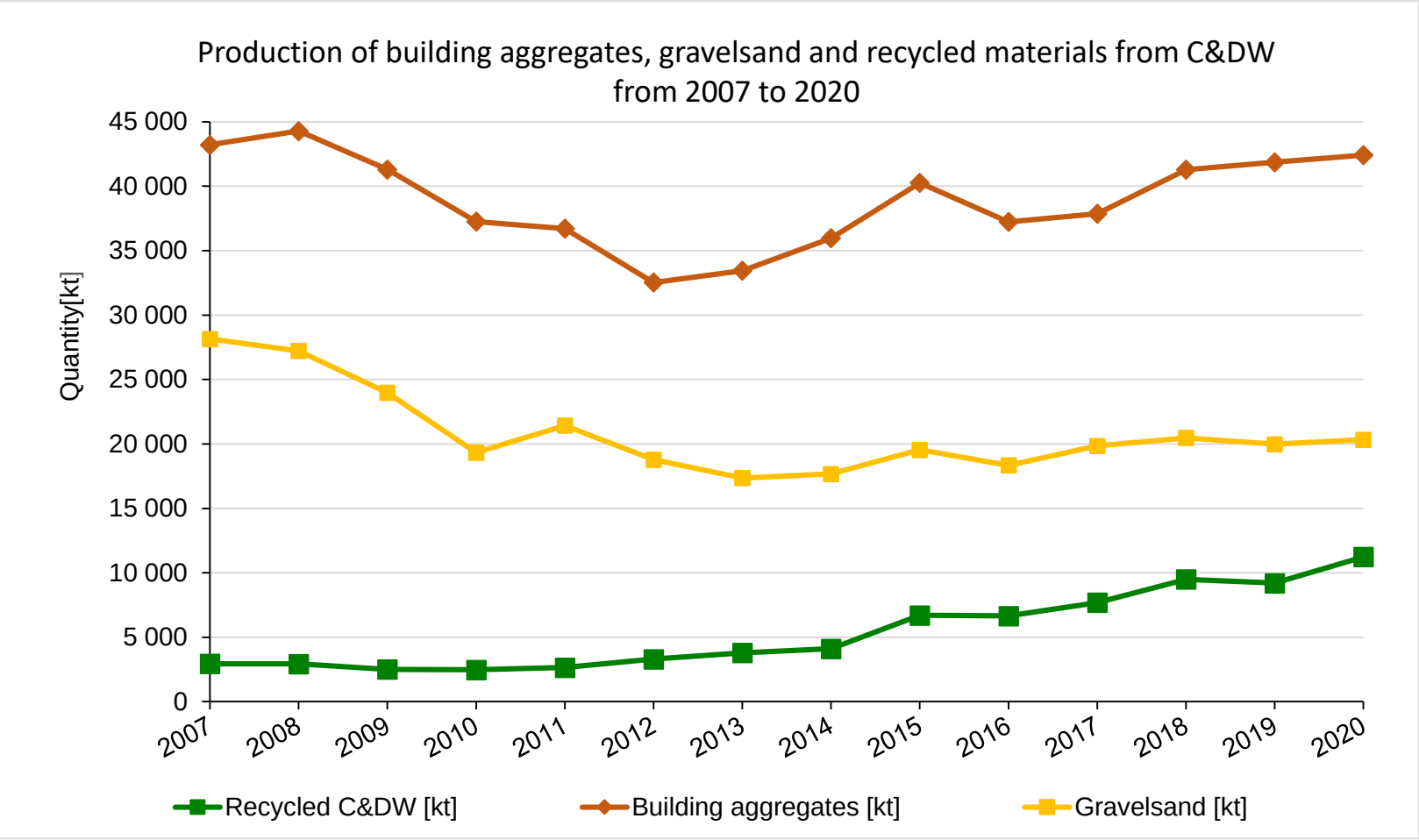


Relative production of the main kinds of waste code 1701

Code C&DW 1701 - Concrete, bricks, tiles and ceramics

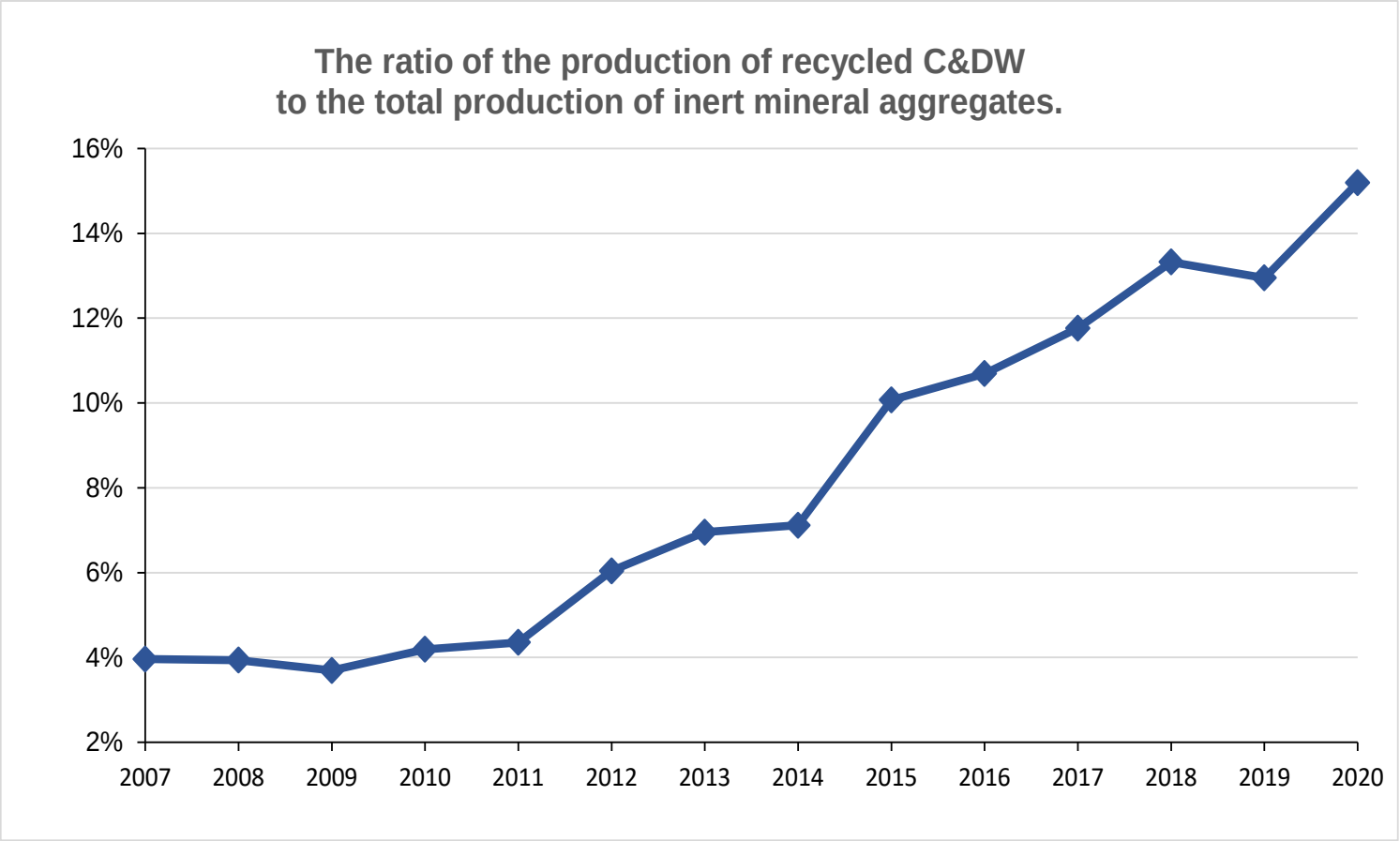
- Approximately 10 to 11 million m^3 of concrete is produced annually in the Czech Republic,
- consumption of natural aggregates for the production of concrete approx. 16 to 18 million tons per year,
- 30 % to 50 % of the production of concrete and brick waste could be used for the production of concrete - i.e. 1.5 to 2.5 million tons/year,
- this would lead to a reduction in the requirements for filler from natural mineral raw materials by approximately 10 % to 13 %.

Analysis of the substitution of recycled building materials for natural aggregates and gravelsand



Production of building aggregates, gravelsand and recycled materials for C&DW from 2007 to 2020

Analysis of the substitution of recycled buildin materials for natural aggregates and gravelsand



$$PPR = \frac{PR}{PR+PSK+PSP} \cdot 100 \quad [\%]$$

PR …. Production of recycled C&DW [kt]

PSK .. Production of building aggregates [kt]

PSP .. Production of gravelsand [kt]

The ratio of the production of recycled C&DW to the total production of inert mineral aggregate for the construction industry.

Possibilities of using concrete and brick recyclates for concrete production

prof. Ing. Rudolf Hela, CSc.
Brno University of Technology
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Properties of recyclates

Concrete recyclate :

- Bulk density: approx. 15% lower than PK
- Absorption :
  - Coarse aggregate : 4-9 %
  - Fine aggregate : until 12 %
- Suitable shape index

Brick recyclate :

- Bulk density: approx. 30% lower than PK
- High water absorption: up to 25 %
- Inferior physical properties

Pollutants

- Calcium sulphate (Gypsum) → formation of ettringite
- Chlorides
- Magnesium oxide (MgO) → formation of $Mg(OH)_2$
- Foreign particles
- Possible occurrence of reactive SiO_2 in concrete recyclate → Alkaline-silica reaction

Legislative measures

- Currently according to EN 206-1
- Compared to developed European countries, our standards and regulations are slightly behind in terms of recycled aggregates

A type of recycled aggregate	Degrees of environmental influence			
	X0	XC1,XC2	XC3,XC4,XF 1,XA1, XD1	All other degrees
Type A: (Rc_{90}, Rcu_{95}, Rb_{10-}, Ra_{1-},FL_{2-}, XRg_{1-})	50 %	30 %	30 %	0 %
Type B: (Rc_{50}, Rcu_{70}, Rb_{30-}, Ra_{5-},FL_{2-}, XRg_{2-})	50 %	20 %	0 %	0 %
pozn. Recycled aggregate of type A from a known source may be used for the environmental grades for which the original concrete was designed, with a maximum of 30 % replacement. **Recycled aggregate type B is not used in concrete strength class > C 30/37.**				

Recommendations for coarse recycled aggregates according to EN 12620

Properties	Article in EN 12620:2002 + A1:2008	Type	Category according to EN 12620
Fine particle content	4.6	A+B	Category or declared value
Index of flatness	4.4	A+B	≤ Fl_{50} nebo ≤ Sl_{55}
Resistance to crushing	5.2	A+B	≤ LA_{50} nebo ≤ SZ_{32}
Bulk density of dried grainsρ_{rd}	5.5	A	≥ 2100 kg/m^3
		B	≥ 1700 kg/m^4
Grain absorption	5.5	A+B	The value must be determined
Components	5.8	A	Rc_{90}, Rcu_{95}, Rb_{10-}, Ra_{1-},FL_{2-}, XRg_{1-}
		B	Rc_{50}, Rcu_{70}, Rb_{30-}, Ra_{5-},FL_{2-}, XRg_{2-}
Water-soluble sulphates	6.3.3	A+B	≤ $SS_{0,2}$
Water-soluble chloride ion content	6.2	A+B	The value must be determined
Effect on the onset of solidification	6.4.1	A+B	≤ A_{40}

Permissible content of materials in recyclate

Type of matter	Percentage content by weight of each type of recyclate	
	Type 1	Type 2
	grit or sand made by crushing only concrete (concrete grit)	gravel or sand produced by crushing construction debris
Concrete and aggregates according to EN 12620	≥ 90	≥ 70
Sintered ceramics, not porous brick shards	≤ 10	≤ 30
Calcareous sandstone		
Other mineral shares[a)]	≤ 2	≤ 3
Asphalt	≤ 1	≤ 1
Other admixtures [b)]	≤ 0,2	≤ 0,5

Absorption and bulk density after 10 minutes

Bulk density and water absorption	Recycle	
	Type 1	Type 2
Minimum bulk density [kg/m³]	2 000	
Allowable tolerance for bulk density [kg/m³]	±150	
Maximum absorbency after 10 minutes, weight ratio [%]	10	15

Germany - DIN EN 206 - for use in concrete max. C 30/37, min. grain size 2 mm

A type of recycled aggregate	Degrees of environmental influence		
	W0, XC1, WF, XC1-XC4	WF, XF1, XF3	WF, XA1
Type 1: (Rc_{90}, Rb_{10-}, Ra_{1-},FL_{2-}, XRg_{1-})	45 %	35 %	25 %
Type 2: (Rcu_{70}, Rb_{30-}, Ra_{1-},FL_{2-}, XRg_{2-})	35 %	25 %	25 %

Legislation in other countries

- In the Netherlands, the legislative measure is a national standard that regulates the regulations for recycled concrete aggregate as aggregate for the production of plain, reinforced and prestressed concrete. When this standard applies if the concrete recyclates are represented in the mix by more than 20%. Where recycled aggregate (both fine and coarse) is present in quantities up to 20 % the standardisation does not apply and the recycled aggregate is taken as natural aggregate.
- The Danish legislation for the substitution of natural aggregates by recycled aggregates according to environmental impacts is based on the European standard EN 206 and is unchanged, i.e. the same as Table 3 above. These regulations are applicable to recycled aggregates of fraction greater than 4 mm and to concrete of maximum strength class C 30/37.

Requirements for concrete recyclate

Properties	Belgium	Germany	Netherlands	Portugal	Czech Republic
Composition [% weight]	≥ 95 % crushed concrete	≥ 90 % crushed concrete	≥ 95 % crushed concrete	≥ 90 % crushed concrete	≥ 90 % crushed concrete
Bulk densiy [kg/m³]	≥ 2200	≥ 2000	≥ 2000	≥ 2200	≥ 2000
Absorption [%]	≤ 10 ± 2	≤ 10	–	≤ 7	≤ 10
Fine particle content [%]	1,5	–	1	4	–

Division of concrete from recycled aggregates according to ČSN P 73 2404

- RC: Recycled Aggregate Concrete (RC Concrete) is a cementitious composite in which the fine and coarse aggregate is completely replaced by recycled aggregate above specified limits and the bulk weight of RC is ≥ 1800 kg/m^3.
- RC-C: Concrete from concrete recycled aggregate The cement composite contains more than 70% concrete recycled aggregate.
- RC-B: Concrete from brick recycled aggregate
- RC-M: Concrete from mixed recycled aggregate
- LCR: Lightweight concrete from recycled aggregate

Impacts on fresh concrete

Concrete with concrete recyclate :

- Deterioration of consistency
- Increase in the amount of water used (5 to 15%)
- The effect is mainly due to the fine and fine fraction

Concrete with brick recyclate :

- Deterioration of consistency
- Influence especially the 4/8 mm batch fraction
- Increase the amount of mixing water or pre-soak the aggregate

Impacts on hardened concrete

Concrete with concrete recyclate :

- Lower bulk density
- 4-20 % decrease in compressive strength
- 10-30 % decrease in static modulus of elasticity
- Increase in creep coefficient up to 50%
- Increase in concrete shrinkage by 20-40%
- Increased water absorption by 20-100%
- Decrease in frost resistance (unsuitable fine fraction)
- Decrease in chloride resistance (can be partially addressed with fly ash)

Impacts on hardened concrete

Concrete with brick recyclate :

- Lower bulk density
  - For density > 2000 kg/m^3 replace the fraction 8/16 mm PK
- The ratio of compressive strength to tensile strength is approximately 1:10
- 30-50 % decrease in static modulus of elasticity
- Increased concrete shrinkage in air and volume gain under water by 10-20%
- Freezing resistance for 150 freezing cycles under the condition of replacing the 0/4 mm PK fraction

Experimentally verified recipes

Brick Concrete C 20/25

Components	1 m^3
Cement CEM I 42,5 R [kg]	305
Fly ash [kg]	60
Mapei Dynamom SX14 [kg]	3,1
Water [kg]	180
Water to moisten the aggregate to 15% [kg]	170
Water for mixing concrete [kg]	290
Rb 0/8 mm dried [kg]	833
Rb 8/16 mm dried [kg]	360
Aggregate Rb in total [kg]	1193
Water cement ratio [-]	0,88

Experimentally verified recipes

Brick Concrete C 30/37

Components	1 m^3
Cement CEM I 42,5 R [kg]	365
Fly ash [kg]	80
Mapei Dynamom SX14 [kg]	3,6
Water [kg]	187
Water to moisten the aggregate to 15% [kg]	165
Water for mixing concrete [kg]	298
Rb 0/8 mm dried [kg]	745
Rb 8/16 mm dried [kg]	367
Aggregate Rb in total [kg]	1112
Water cement ratio [-]	0,75

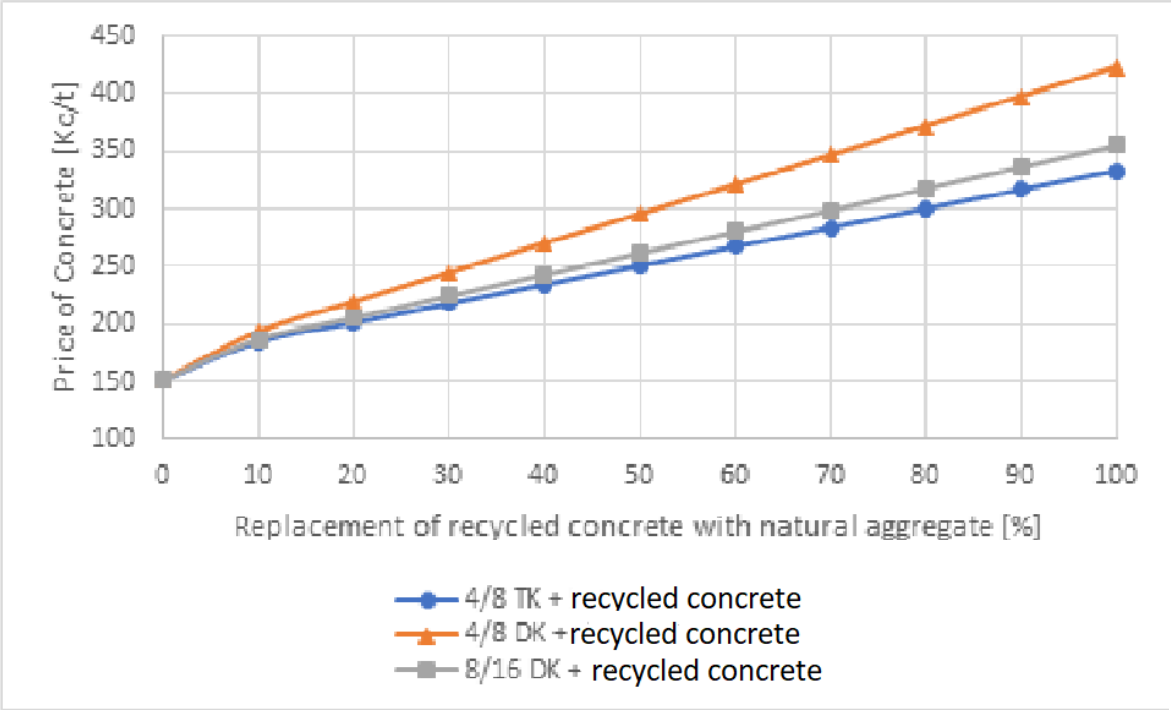
Concrete with concrete recyclate C 20/25

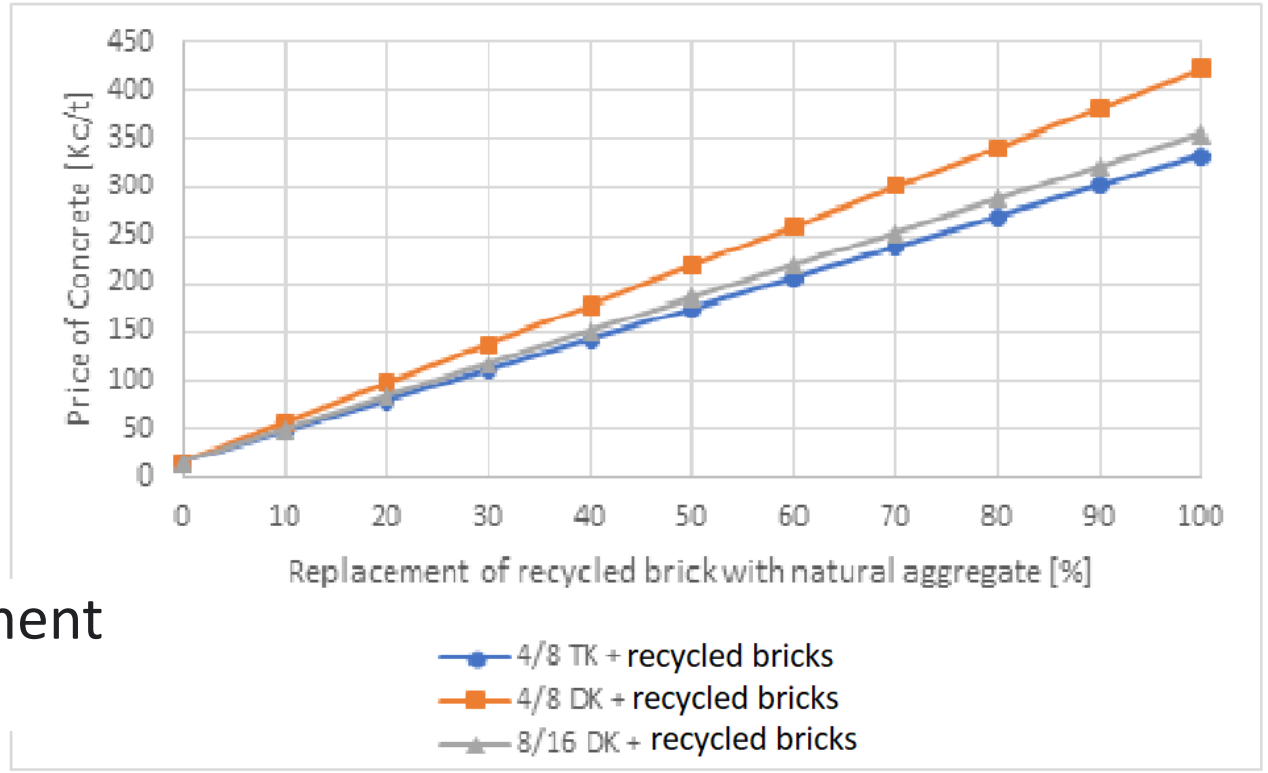
Components	1 m^3
Cement CEM I 42,5 R [kg]	335
Mapei Dynamom SX14 [kg]	3,3
Sand 0/4 [kg]	875
Rc 4/8 mm [kg]	241
Rc 8/16 mm [kg]	565
Water for mixing concrete [kg]	188
Water cement ratio [-]	0,56

Concrete with concrete recyclate C 30/37

Components	1 m^3
Cement CEM I 42,5 R [kg]	380
Mapei Dynamom SX14 [kg]	3,8
Sand 0/4 [kg]	852
Rc 4/8 mm [kg]	235
Rc 8/16 mm [kg]	550
Water for mixing concrete [kg]	192
Water cement ratio [-]	0,51

- Price impact on the percentage replacement of natural aggregates with recycled concrete





- Price impact on the percentage replacement of natural aggregates with recycled brick

Conclusion

- Conservation of natural aggregate resources and the environment
- Concrete and brick recyclates have been shown to degrade the properties of both fresh and hardened concrete
- The maximum suitable replacement of natural aggregates with recyclates is :
  - Concrete recyclate: fines up to 10 %, coarse up to 100 %
  - Brick recyclate: fines up to 0 %, coarse up to 80 %
- Favourable prices of recyclates lead to lower costs of aggregates for concrete