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The French National Project on Complete Recycling of Concretes (RECYclage complet des BETONS)



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Impacts énergétiques,
environnementaux et
sanitaires

- Need to preserve the natural aggregate sources (difficulties to open new quarries)
- Need to manage the increasing flow of construction & demolition materials generated by the cities
- Need to permanently suppress all landfills
- Need to decrease materials transportation distances
- Need for the concrete sector to catch up with other recyclable construction materials



It is imperative to promote and develop recycling of concrete into concrete





- A 4.7 M-€ R&D program supported by the French Ministry of Ecology
- 47 partners (industry + academia) including all related professional unions (cement, aggregate, ready-mix concrete, prefabrication, building, civil-engineering, etc.)
- Comprehensive coverage of the topic, from material science to demonstration sites and proposals for standard evolutions
- More than 100 researchers involved
- Complemented by the **ECOREB** (ECOconstruction par le REcyclage du Béton, Ecoconstruction with Concrete Recycling), project supported by ANR (Agence Nationale de la Recherche, National Research Agency)

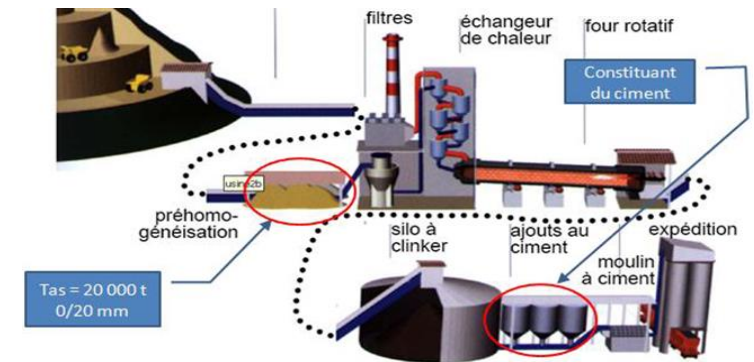




➤ To recycle all the materials obtained from demolished concrete, even the fines (as sand or addition), as components of new concretes



➤ To recycle the fine grain size part of demolished concrete as raw material for the manufacture of cements (either to produce clinker or as a component of blended cements)





- **Theme 0 - Technical support:** Formulation of concrete mixes and provision of homogeneous materials for the researches
- **Theme 1 - Technologies and processes:** Crushing and sorting of demolished concretes, and Cement and Concrete manufacturing with recycled concrete aggregates
- **Theme 2 - Materials and structures:** Improvement of recycled concrete aggregates to be used for making concrete, properties at early age and hardened state, durability and fire resistance of recycled concretes
- **Theme 3 - Sustainable development:** Socio-economic, environmental and sanitary impacts of the development of the concrete recycling sector
- **Theme 4 - Standard and normative aspects:** Detection of barriers and incentives at French, European and International levels for making proposals of adjustments and/or modifications to the existing regulation
- **Theme 5 - Communication and promotion:** Showing off the National Project advances : conferences, publications and experimental demonstration sites
- **Theme 6 - Blends of natural aggregates with low rates of recycled concrete aggregates :** Performances of low rates of recycled concrete aggregates mixed with natural aggregates directly in the quarries.





➤ Theme 0 – Technical support

- Constitution of homogeneous stocks of natural and recycled aggregates, and of cements
- Formulation of six C25/30 and three C35/45 concrete compositions with different % of recycled aggregates (sand and/or gravel) including their respective reference formulas (0R, 0R)

Concretes used in French National Project RECYBETON

Formulation N°	Strenght Class	Ciment	Addition	Sand	Gravel
1	C25/30	CEM II	Limestone filler	0R	0R
2	C25/30	CEM II	Limestone filler	0R	30R
3	C25/30	CEM II	Limestone filler	0R	100R
4	C25/30	CEM II	Limestone filler	30R	0R
5	C25/30	CEM II	Limestone filler	30R	30R
6	C25/30	CEM II	Limestone filler	100R	100R
7	C35/45	CEM II	Limestone filler	0R	0R
8	C35/45	CEM II	Limestone filler	0R	100R
9	C35/45	CEM II	Limestone filler	30R	30R

R : Recycled Concrete Aggregate





➤ Theme 1 - Technologies and processes

1.1 Crushing and Sorting

- No major differences on the quality of recycled concrete aggregates according to the crusher type (jaw, gyratory or impact crusher)
- Recycled Concrete Aggregate used as obtained: porous and possibly polluted
- Automatic techniques for the detection of pollutants, for sorting and splitting paste/aggregate were inventoried. Some of them may be soon affordable

1.2 Cement incorporating materials from recycled concrete

- Recycled Concrete Fines (recycled sands) were used:
 - As a part of raw meal (15%) to produce clinker: Industrial production of good clinker, experimental production of cement (CR1, equivalent CEM I)
 - As mineral addition to make blended cement: Performs as a filler; experimental production of blended cement (CR2, equivalent CEM II)
 - As supplementary cementitious material to concrete: Low activity

1.3 Concrete incorporating materials from recycled concrete

- Interest in pre-saturating recycled aggregates
- No special difficulty concerning batching, mixing or pouring concrete containing recycled aggregates





➤ Theme 2 - Materials and structures (1)

2.1 Recycled aggregates and fines

- The applicability to recycled concrete aggregates of existing standards test for natural aggregates was checked: Measure of water absorption of recycled sands, microbar test (for alkali-aggregate reaction) has to be adapted

2.2 Recycled concrete at early age and during hardening

- Initial rheology: Impaired by recycled sands (more admixtures needed)
- Rheology evolution: A little impact of differed water absorption of recycled gravels

2.3 Hardened recycled concrete – Mechanical behavior

- Impact on f_c : Depends on quality of parent concrete, recycled aggregate rate and targeted strength
- Impact on f_t / f_c ratio: Depends on the nature of parent aggregate
- Systematic effect on E-modulus (\downarrow), shrinkage and creep (\uparrow)
- Fatigue strength in flexion: slightly degraded for high rate of recycled aggregate content





➤ Theme 2 - Materials and structures (2)

2.3 Hardened recycled concrete – Mechanical behavior (continuation)

- Structural behaviour:
 - Steel/concrete bond not markedly modified
 - Behaviour of short columns unchanged
 - Beams under flexure: higher displacement, comparable crack opening
 - Shear behaviour: concrete contribution depends on ft

2.4 Hardened recycled concrete – Durability

- At equal strength, porosity, permeability and Chloride diffusivity increase
- Carbonation is slightly affected
- Recycled aggregates may be degraded by freeze/thaw (depending on parent concrete)

2.5 Recycled concrete – Fire and thermal behavior

- Thermal conductivity is lower when RA are incorporated
- Similar structural and scaling behaviour as ordinary concrete

Some subjects concerning this theme were considered in a complementary project founded by the French National Research Agency (ANR), the **ECOREB Project** (ECOconstruction par le REcyclage du Béton – Environmental friendly construction by recycling concrete)



➤ Theme 3 - Sustainable development

3.1 Social and economical aspects

- Available resources: About 70 Mt/year of pure concrete + mixed demolition materials (containing concrete and natural rocks), where 38 Mt are potentially recyclable in concrete
- Approximately 20 Mt of the demolition waste potentially recyclable contains only concrete or concrete mixtures

3.2 Environmental and health aspects

- Leaching tests: Measured on recycled aggregates and on concrete containing recycled aggregates. The release threshold values are not reached
- Life Cycle Assessment (LCA):
 - Environmental Product Declaration (EPD) for recycled aggregates
 - LCA performed for various recycled concrete
 - Critical terms (CO₂): Cement content (higher for higher rates of recycled aggregates, specially 100 %) and transport distance of recycled aggregates
 - Recycling benefits (hardly displayed by conventional LCA): natural resource economy + avoidance of landfill





➤ Theme 4 - Standard and normative aspects

Standards review in various countries

- Complete overview of general concepts and standards at European and International levels. Some countries are quite advanced (ex. Switzerland)

Current status in France

- Recycled aggregates considered in the product standard on aggregates for concrete (NF EN 12620)
- Concrete standard EN 206/CN allows the use of recycled aggregates at low rate and for not severe environments
- Fascicle 65: more severe. Only if the traced aggregate origin is from a similar work
- Eurocode 2 does not explicitly address recycled concrete aggregates

Standard evolutions

- Proposal to increase the application field (in terms of rate and environments) + standards for precast concrete products using recycled aggregates + adaptation of Eurocode models
- Some evolution of test standards should be considered

Environmental labels

- French HQE should evolve to follow LEED, BREEAM, MINERGIE



➤ Theme 6 - Blends of natural aggregates with low rates of recycled concrete aggregates

- Theme added at the last time of the project to consider another way to use recycled aggregates, mixed with natural aggregates directly in the quarries
- Performances of blends at low rate of incorporation of recycled aggregates: No appreciable difference below a rate of 10% of recycled aggregates incorporated to the mix
- Need of some more research in all properties to define if these blends could be considered like natural aggregates in any case



➤ Theme 5 - Communication and Promotion – Dissemination (1)

Demonstration Sites (experimental constructions)

- 5 experimental constructions using concrete with recycled aggregates (an external car-park, a bicycle bridge, an archive room for a library, a sidewalk and low walls in a ready-mix concrete plant and an internal slab of an office building)
- A slab with concrete made with recycled cement CR1 in the car-park demonstration site
- Precast elements in concrete with recycled aggregates



Car-park experimental demonstration site
Recycled aggregate rates: 0, 30 and 100%

Construction date: December 2013
No damage observed until today



➤ **Theme 5 - Communication and Promotion – Dissemination (2)**
Demonstration Sites (experimental constructions)



Bicycle bridge demonstration site
Recycled aggregate rate: 20 % (40% also tested in lab)

Construction date: June – July 2014
No damage observed until today



Core sampling in testing wall



➤ **Theme 5 - Communication and Promotion – Dissemination (3)**
Demonstration Sites (experimental constructions)



**Archive room
 demonstration site
 Recycled aggregate rate: 30% Sand
 and 50% gravel**



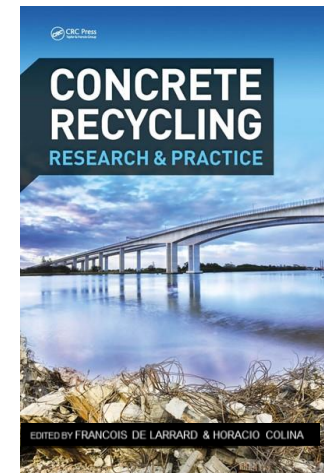
**Construction date: Octobre 2015
 No damage observed until today**



➤ Theme 5 - Communication and Promotion – Dissemination (4)

Deliverables

- 52 scientific and technical reports: Almost all of them will be accessible to public
- A scientific book: French version just published, English version in March 2019
- A Recommendations guidance for the professionals: Just printed
- Proposal for Standards evolution and Incentive measures: At the beginning of 2019



Public events

- Scientific Conferences: 1st on June 2015, 2nd on March 2017
- Restitution events: First one on 27th November 2018 at Lyon (Pollutec 2018)
- Closure event on 12 March 2019 at Paris, then in three or more other French cities





- After 6 years of collective work, the French construction community has increased its awareness about complete recycling of concrete
- Most technical problems to recycle concrete into concrete were addressed, but none of them appears to be a roadblock. Only some adjustments to be done when using recycled concrete aggregates
- The National Project RECYBETON has produced all the necessary tools allowing the use of this potential resource into concrete
- A gradual change in the current practices must happen to reach this important goal, requiring efforts from all stakeholders (owners, specifiers, material industry) and decision-makers
- The French concrete community must catch up, as compared to competing materials and to other countries, to enter in the circular economy





THANK YOU FOR YOUR ATTENTION

