Metropolitan College of Thessaloniki
Faculty of Architecture, Engineering and the Built Environment
BEng (Hons) Civil Engineering and Construction

# *Construction and Demolition (C&D) Waste: Potential uses and current situation in Greece and Cyprus*

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# DEFINITION OF C&D WASTES

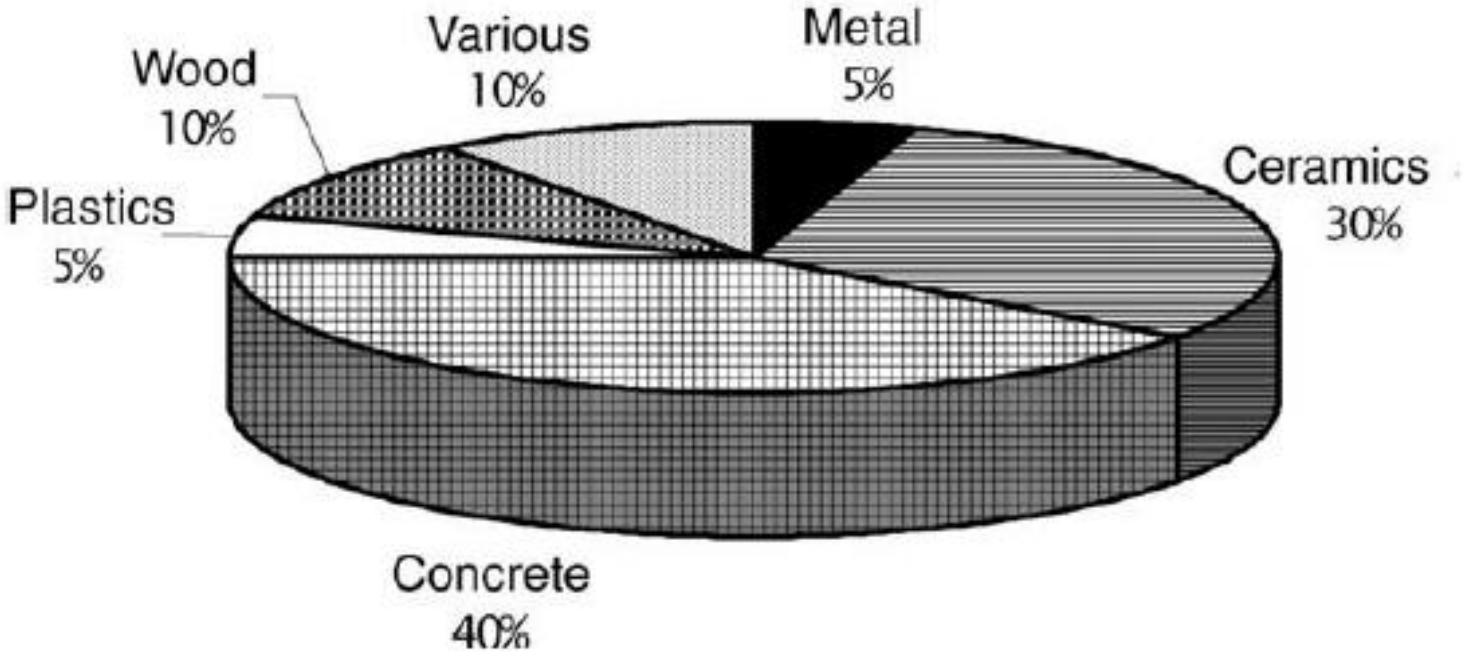
According to their origin, they can be divided into:

1. Construction and demolition materials from buildings and infrastructure such as concrete, aggregates, wood, bricks and other building materials as well as road materials such as bituminous mixtures as well as aggregates of various particle sizes.

2. Materials from physical disasters (earthquakes/ floods/etc).

3. Excavation materials, such as excavated soil, sand, gravel, rocks etc, which arise almost in every construction activity, especially during foundation and geotechnical engineering works.

# COMPOSITION OF C&D WASTES




*Source: N. Oikonomou, 2005*

# VOLUME OF C&D WASTES

Volume of C&D Wastes produced depends on factors such as:

- population growth,
- city or regional planning,
- state of construction industry
- economic reasons (the quantities of C&D waste generated is highly dependent on the rate of new constructions, which is related to the economic growth of the country),
- regional variation of the types of materials used in construction (since in some regions brick is the main construction material, whereas in others concrete represents the majority; wood is a major construction material in northern countries like Finland or Sweden, etc.).

# CONSTRUCTION AND DEMOLITION WASTE IN EU

Construction, demolition and excavation waste (CD&E Waste) is one of the most significant waste streams in the EU, accounting for **approximately 750 million tons per year**, while this category accounts for approximately 25% - 30% of all waste generated in the EU.

# INDICATIVE C&D WASTE GENERATION [BIO Intelligence Service, 2011]

| Country | Arising (TONS/CAPITA) |
|---|---|
| Austria | 0,81 |
| Belgium | 1,06 |
| Bulgaria | 0,39 |
| Cyprus | 0,58 |
| Czech Republic | 1,44 |
| Denmark | 3,99 |
| Estonia | 1,12 |
| Finland | 3,99 |
| France | 5,5 |
| Germany | 2,33 |
| Greece | 0,37 |
| Hungary | 0,43 |
| Ireland | 2,74 |
| Italy | 0,8 |
| Latvia | 0,04 |

| Country | Arising (TONS/CAPITA) |
|---|---|
| Lithuania | 0,1 |
| Luxembourg | 5,9 |
| Malta | 1,95 |
| Netherlands | 1,47 |
| Norway | 0,7 |
| Poland | 0,11 |
| Portugal | 1,09 |
| Romania | N/A |
| Slovakia | 0,26 |
| Slovenia | N/A |
| Spain | 0,74 |
| Sweden | 1,14 |
| United Kingdom | 1,66 |
| EU27 | 1,74 |

- Denmark, Finland, France, Germany, Ireland and Luxembourg: high (>2tons/yr/capita
- Bulgaria, Greece, Hungary, Latvia, Lithuania, Poland and Slovakia: low (<500kg/yr/capita). Cyprus generates ~580kg/yr/capita

# DIFFERENCES IN QUANTITIES

The main reasons for the discrepancies noticed are the unequal levels of control and reporting of C&D waste in each Member State (MS), as well as differences in definitions and reporting mechanisms.

The quality of the available data is therefore the main issue in estimating the quantities of C&D waste generated.

# LEGAL FRAMEWORK-GREECE


- European Directive 98-EU-2008
- Law 2939/2001
- Law 3854/2010 (modification of previous law)
- JMD36259/1757/E103/2010 (C&D Wastes, Solid Marble Wastes, concrete), JMD 50910/03, Law 4030/2011-paragraph 4
- Law 4042/2012-part B
- Law4067/2012 (New Construction Code)
- Joint Ministerial Decision 36259/1757/E103 (Gov. Gazzete, second issue, 1312/24.8.2010)

*http://roboticworld.net/laws-of-robotics.html*

# LEGAL FRAMEWORK-CYPRUS


The Law 215 (I)/2002 (the Solid and hazardous waste Act of 2002) which applied for the management of solid and hazardous waste

Law189/2011 harmonizing Cypriot law with EC 98/2008 of the European Parliament and the Council on 19th of November 2008 on waste (replacement of previous).

Law (Κ.Δ.Π. 159/2011), are being applied under which the "producer responsibility" for waste Excavating construction and demolition waste is documented.

Law (Κ.Δ.Π. 220/2013) on C&D Wastes' management

# LEGAL FRAMEWORK- EU-GREECE-CYPRUS

## Quantitative targets for both countries

| 1/1/2012 | 1/1/2015 | 1/1/2020 |
|---|---|---|
| **> 30%** | **> 50%** | **> 70%** |
| Reuse, recycling recovery | Reuse, recycling recovery | Reuse, recycling recovery |

*In particular, energy recovery is excluded from this scope, while category 17 05 04 (excavated material) is not included in the calculation of the target.*

# ESTIMATIONS OF QUANTITIES IN GREECE

Estimations based on construction and demolition licenses.

Not available detailed data concerning the exact amount of C & D waste generation.  WHY????

- Large quantities illegally deposited in various places all around Greece.
- Construction companies not obliged to monitor and report the quantitative characteristics of their wastes in a collective legal system until 2010.

# ESTIMATIONS OF QUANTITIES IN GREECE

| Year | Quantities of C&D Wastes (tons) |
|---|---|
| 1996 | 1.636.298 |
| 1997 | 2.006.625 |
| 1998 | 2.130.939 |
| 1999 | 1.899.075 |
| 2000 | 2.092.387 |
| 2004 | 3.324.000 |
| 2006 | 6.829.161 |
| 2008 | 6.828.051 |

Total estimated quantities of C&D Wastes, (excluded excavation waste) for the years 1996-2000, 2004, 2006 and 2008 in Greece.

*Source:*
*Fatta, D. et al, 2003,*
*http://ec.europa.eu/environment/waste/pdf/2011_CDW_Report.pdf, accessed 19 April 2015*

# ESTIMATIONS OF QUANTITIES IN CYPRUS

Statistical Office retains construction permits, surface elements of new buildings and additions to existing buildings, and on this basis, the estimation of the produced C&D waste in the provinces, will be conducted.

A model from the Department of Chemical Engineering of NTUA has been used.

# ESTIMATIONS OF QUANTITIES ACCORDING NTUA'S MODEL

The quantity of **construction waste** is calculated from the equation:

$$CW = [NC + EX] * VW * D$$

where:
CW: Construction Waste in tons
NC: Plan area of the new constructions
EX: Additions to existing buildings
VW: Volume of the produced waste by square meters of new buildings
D size: Waste density

# ESTIMATIONS OF QUANTITIES ACCORDING NTUA'S MODEL

The **demolition waste** equation has the form:

DW= ND*SD*WD*D

where:
DW: Demolition Waste in tons
ND: Number of Demolitions
SD: Average surface area of demolished buildings
WD: Waste Produced for each demolition
D: Waste produced density

# ESTIMATIONS OF QUANTITIES ACCORDING NTUA'S MODEL

The equation for the **excavation waste** is:

EW = ND * ES * ED * D

where:

- EW: Excavation Waste in tons
- ND: New construction permits' number
- ES: Mean surface area of the excavation
- ED: Average depth of excavation
- D: Density of waste produced

# ESTIMATIONS OF QUANTITIES ACCORDING NTUA'S MODEL

| PARAMETER | CYPRUS |
|---|---|
| Construction Waste volume per new built surface | 0,1 $m^3/m^2$ |
| Construction Waste Density | 1,2 tn / $m^3$ |
| Average Buildings' size | 370 $m^2$ |
| Average number of floors per building | 1.5 |
| Demolition waste volume per building surface | 1,5 $m^3/m^2$ |
| Demolition Waste Density | 1,5 tn / $m^3$ |
| Average Excavation Surface | 250 $m^2$ |
| Average Depth Of Excavations | 2 m |
| Waste Density of Excavations | 1,4 tn / $m^3$ |

# ESTIMATIONS OF QUANTITIES IN CYPRUS

Number of New Permits

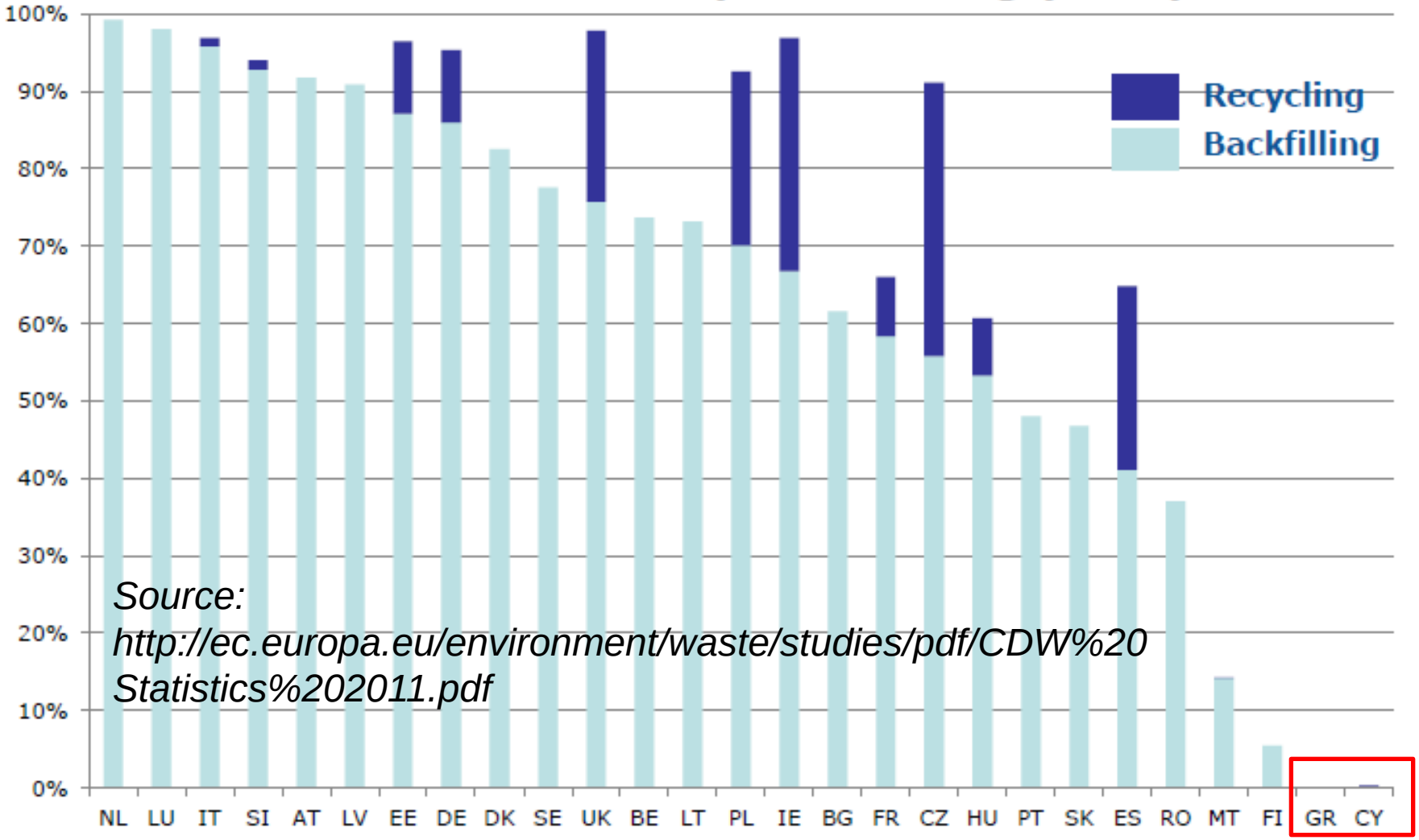
| YEARS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
| 8.252 | 9.098 | 9.794 | 9.521 | 8.896 | 8.950 | 8.777 | 7.506 | 7.172 | 5.341 |

2012-2013: Economic crisis

Total produced C&D Wastes in Cyprus(tn) as calculated by the use of NTUA's model

| PRODUCED WASTES | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Average |
| Construction | 442.693 | 376.375 | 350.149 | 269.275 | 179.984 | 148.532 | 308.488 |
| Demolition | 226.440 | 0 | 0 | 0 | 0 | 0 | 63.119 |
| Excavation | 6.227.200 | 6.265.000 | 6.143.900 | 5.254.200 | 5.020.400 | 3.738.700 | 5.301.355 |
| TOTAL | 6.896.333 | 6.641.375 | 6.494.049 | 5.523.475 | 5.200.384 | 3.887.232 | 5.672.961 |

# MATERIAL RECOVERY & BACKFILLING (2011)




*Source: http://ec.europa.eu/environment/waste/studies/pdf/CDW%20Statistics%202011.pdf*

# COLLECTIVE SYSTEMS OF C&D WASTES IN GREECE

- ANAKYKLWSI ADRANWN VOREIOU ELLADOS (AN.A.B.E)
- ΣΑΝΚΕ ΕΠΕ (Collective System for C&D Waste Management of Central Greece)
- Recycling System ΣΕΔΠΕΚΑΤ SA, Athens
- Recycling of Chalkidiki OE* (under licensing from Hellenic Recycling Association)
- Recycling of C&D of Central Macedonia (EKKA SA)
- Psarras Alternative Management (AEMKE)
- Aggregates' Recycling of N. Greece

Under licensing: ~13 all over Greece (Crete, Attiki, Viotia, Evoia, Evritania…)

# MANAGEMENT OF C&D WASTES IN GREECE

Start: 2011

Establishment and licensing of the first Collective Alternative Management System which is located in Thessaloniki.

From 2012 until 2014, collection systems adopted came up to 9, covering 18 geographical regions.

According to statistics maintained by the Greek Recycling Organization, the amount of C&D Wastes managed in 2012 was more than 12.000tn*, for 2013 around 50.000tn, while for 2014 more than 20.000tn* (*: data only from treatment plant “Anakyklwsis Adranwn Makedonias SA”).

# MANAGEMENT OF C&D WASTES IN GREECE

The amount collected from the Alternative Management Systems is a very low percentage compared to the quantity of C&D Wastes believed to have been produced and which comes up to around 2.000.000tn.

# ALTERNATIVE TREATMENT PLANT IN THESSALONIKI GR, ANAKYKLWSI ADRANWN MAKEDONIAS S.A.

- Anakyklwsis Adranwn Makedonias SA has been founded on 2004 and is cited outside the region of Thessaloniki.
- It is the first unit all over Greece related to management of Construction and Demolition Wastes (C&D W) of the city and the wider region.
- The unit, of Netherlands' origin, consists of two production lines, one for materials without impurities such as plastic, wood, glass etc, and the other one for the rest of C&D Materials.
- Production of secondary materials is controlled and certified according ISO 9001:2008 and ISO 14001:2004.

# ALTERNATIVE TREATMENT PLANT IN THESSALONIKI GR, ANAKYKLWSI ADRANWN MAKEDONIAS S.A.

Unit's capacity comes up to 350tons/h.

**Production stages**

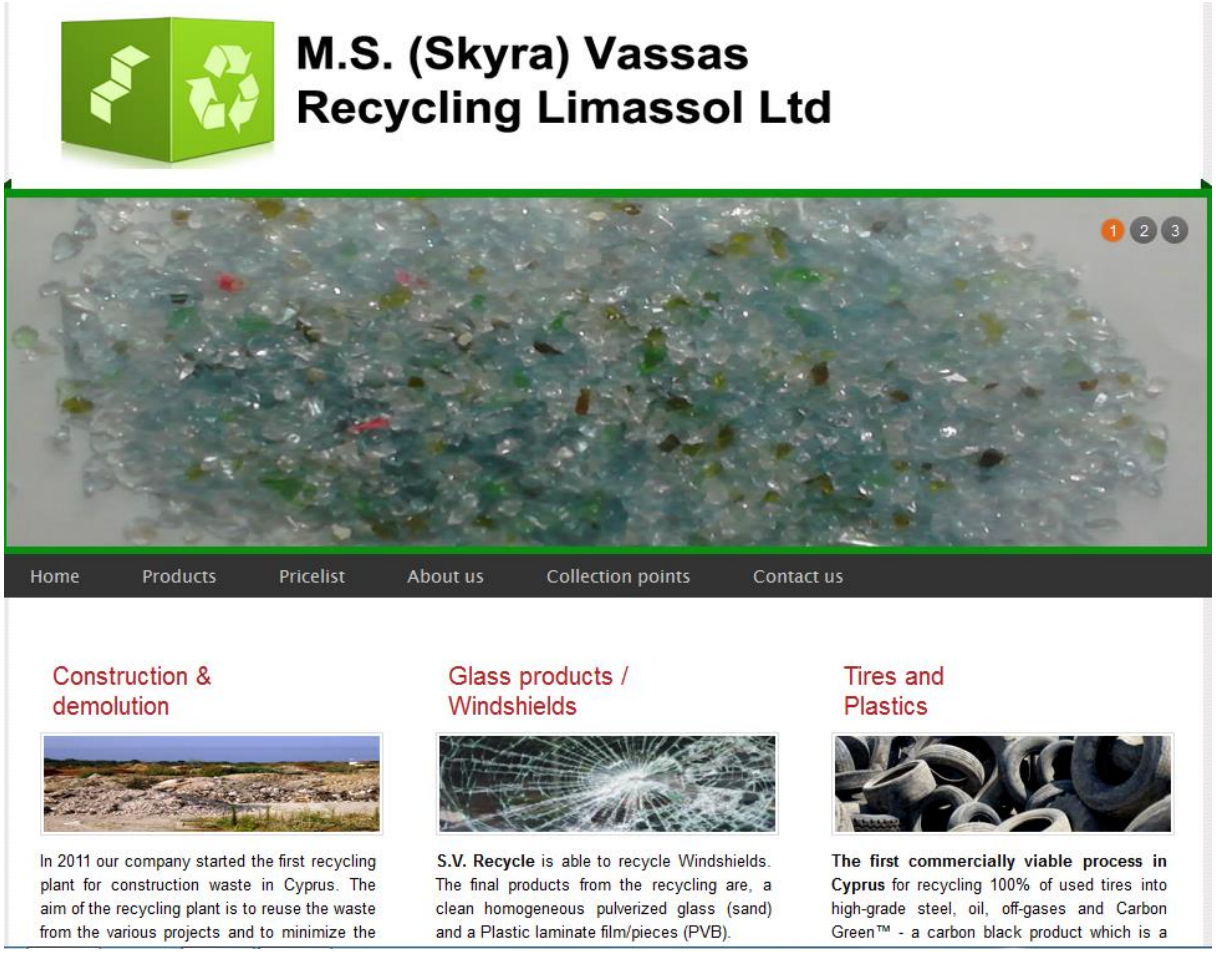
- Presorting (preliminary clearing, hand pick station, large volume items)
- Crushing, metal extraction with magnets
- Sieving, grading
- Final product sorting

# MANAGEMENT OF C&D WASTES IN CYPRUS

There are two processing units SKYRA VASSAS and SKYRA LIMA, while the current practice is the discarding in illegal and largely uncontrollable sites.


*http://www.skyravassas.com/*

# SKYRA VASSAS- IN CYPRUS




- **SKYRA VASSAS LTD**- Limassol- starts operating in 2011
- 200tons/h: treatment capacity
- Quantities for treatment: 21.001tons (3/2012-8/2012).

http://recycle.skyravassas.com/

# SKYRA LIMA- IN CYPRUS

- **SKYRA LIMA LTD-**Larnaca- starts operating 22/5/2012-13/5/2017 (licenced)

330.000tons/yr: treatment capacity

Quantities for treatment: 30.797ton (-9/2013), 27.300ton have been treated.

*http://www.aggbusiness.com/sections/quarry-profiles-reports/features/skyra-limas-output-increases/*

# POTENTIAL RECYCLING RATE IN CYPRUS

Regarding the qualitative composition of C&D waste, although the sample of them arriving at the C&D waste processing units is small, it is however considered the only reliable source to reflect reality.

# FEES FOR C&D WASTES IN GREECE

Gate fee for C&D (mixed debris) at the treatment units in Greece > 2-25€/ton.

The prices of the treated aggregates depending on the screening and the quality may fluctuate from 3€/ton.

# FEES FOR C&D WASTES IN CYPRUS

Gate fee for C&D (mixed debris) at the treatment units in Cyprus > 30€/ton.

The prices of the treated aggregates depending on the screening and the quality may fluctuate from 2 to 5€/ton.

# UTILIZATION OF C&D WASTE IN VARIOUS CIVIL ENGINEERING APPLICATIONS

Composition of C&D Waste includes materials, such as concrete, generally inert materials, asphalt, paper, glass, plastic, wood, bricks etc, depending on the source.

Building and construction waste can be absorbed in various applications/technical projects after appropriate treatment.

Such engineering projects are:

- buildings construction
- road construction
- geotechnical works
- flood defenses
- concrete production
- rail projects
- temporary works.

# UTILIZATION OF C&D WASTE IN VARIOUS CIVIL ENGINEERING APPLICATIONS

C&D Waste's composition is not steady, while there is no CE for those materials.

Every time laboratory tests should take place in order to certify their use as alternative aggregates.

# CONVENTIONAL CONCRETE PRODUCTION-AUTH GREECE

In Lab of Building Materials at the Department of Civil Engineering of Aristotle University of Thessaloniki, many studies have been conducted in order to certify the use of recycled aggregates in concrete production.

Concrete mixtures, conventional and self compacted one, have been produced by the use of recycled aggregates of random composition, age and origin as replacement of part of the natural aggregates.

Recycled aggregates, of various sizes have been supplied by Anakyklwsis Adranwn Makedonias.

# RESULTS AUTH GREECE

- Recycled aggregates are suitable for the production of new concrete mixtures (as far as gradation, Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate, sand equivalent, specific weight and water absorption).

- The use, mainly of coarse aggregates, has potential and can lead to concrete mixtures with satisfactory characteristics and similar to the ones of mixtures with natural aggregates (~49MPa).

- All of the mixtures were found to be cost effective. In particular, when recycled coarse aggregates substituted natural ones of the same gradation, the price of concrete mixture came up to 55,05€, while conventional mixture costs 55,65€.

# SELF COMPACTED CONCRETE-SCC

- Reduced labor since no mechanical vibration is needed.
- Less personnel needed and safer working environment.
- No worry about segregation due to long vibration by vibrator.
- Appropriate for dense reinforcement as well as easy at filling restricted sections and/or hard to reach areas.
- Faster construction since the concrete places quickly.
- Easier to place SCC since it will flow to a long distance easily. No need to move the truck to different placement locations.
- Extremely good finished surface quality—SCC can produce a mirror-like surface and as a result concrete with very fine detail.

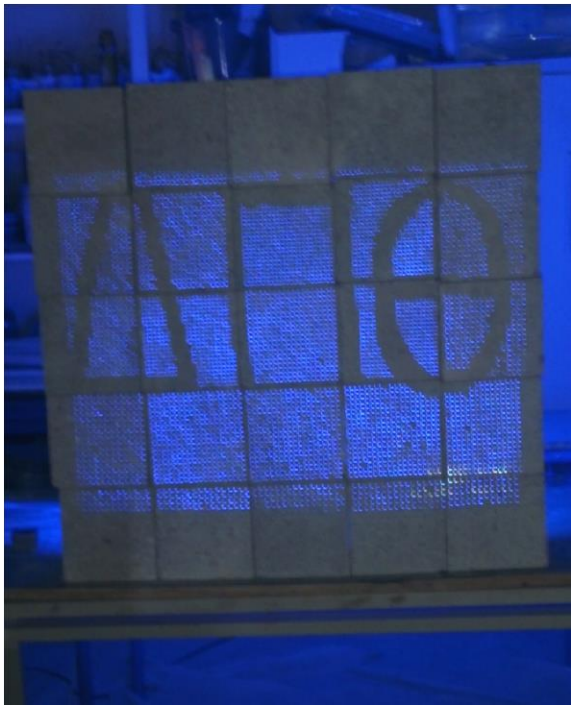
# SCC PRODUCTION- AUTH, GREECE

- ✓ Fines/coarse= 60%/40%.
- ✓ Properties examined included rheological characteristics and mechanical strength.
- ✓ Optimum percentage of substitution was 30% w/t of the aggregates (fine and coarse ones) while compressive strength came up to 28,48MPa.
- ✓ All of the mixtures were found to be cost effective. In particular, when REC recycled 20% of fine aggregates, the price of concrete mixture came up to 66.58€, while conventional mixture costs 67, 65€.

# LIGHT TRANSMITTING CONCRETE PRODUCTION-DUTH, GREECE

REC replaced natural aggregates, while properties examined were compressive strength and durability through carbonation, water permeability, chloride ion penetration resistance as well as resistance to magnesium and sulfate ions.

According to laboratory results, transparent concrete with plastic optical fibres and recycled aggregates show satisfactory characteristics, while compressive strength at 28 days can come up to 22MPa for percentage of optical fibres 1,04v/v.



# GENERAL CONCLUSIONS

- Both countries, Greece and Cyprus are in a turning point for C&D waste management, since there is legislation issued which requires relatively high percentages of recycling of C&D Wastes.
- Up to date, target for 2015 has not been achieved, while satisfaction of next target for 2020 seems too far away.
- No controlling organization of the quantities of CD&E Wastes that are either dumped illegally in sites or collected and utilized as well as a very poor dissemination of current law in wide audience. The limited actions usually depend on the willingness of the responsible people for the construction----estimations.
- In general, in both countries recycling rates are relatively low.

# GENERAL CONCLUSIONS

- It is fortunate that the private sector has already established C&D Wastes' treatment plants, so legislation's implementation is expected to be accelerated, even by their alternative utilization in civil engineering works.

- Secondary materials derived from C&D Wastes are suitable for use, while the undergoing research is promising. Moreover, given that a significant part of C&D Wastes, after appropriate processing, can be recycled, it is understood that any delay in implementing the alternative Management Law of C&D Wastes, is against natural resources, which still are being used at high rates.

# GENERAL CONCLUSIONS

- Up to date, researches in Greek universities certify the alternative management of C&D Wastes in Civil Engineering works and especially in cement or bitumen mixtures with positive and environmentally friendly impacts.

- **Next stage will be further research in Metropolitan College of Thessaloniki.**

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