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

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Abstract

Construction, demolition and Excavation (CD&E) wastes consist of the debris generated during the construction, renovation, and demolition of buildings, roads, and other engineering works. Those wastes may contain bulky, heavy materials, such as concrete, wood, metals, glass, or relatively light such as soil and other building components, which can be recycled and re-used. By reducing and recycling of CD&E wastes a conservation of landfill space as well as reduced environmental impact of producing new materials, creation of jobs and overall reduction of building project expenses through avoided purchase/disposal costs can be achieved.

Present paper is dealing with Construction, Demolition and Excavation Wastes, identifying CD&E as secondary materials that can be utilized in new building projects, thus avoiding the need to mine virgin ones. The structure of the paper is based on two main parts; one concerning technical knowhow in Greece and the other one concerning current situation in Cyprus. Originality of this work is the combination of existing framework in the two countries, dealing with an issue that concerns both. In particular, there are many uses for the products derived from CD&E Wastes, following relevant legislation. However, even if laws issued has been put in order almost 4 years ago, especially in Greece, potential uses of those kinds of wastes are many but only in paper up to date. Moreover, according to laboratory researches conducted in Greece at both Aristotle University of Thessaloniki and Democritus University of Thrace recycled aggregates, given that their characteristics are similar to conventional ones, can be used for the production of new concrete mixtures with satisfactory strength. As far as Cyprus is concerned, a monitoring of existing situation concerning quantitative and qualitative data, as well as possible problems which may be raised in the future will also be presented and compared to the ones in Greece.

In all cases, utilization of CD&E Wastes in civil engineering sector can create a more sustainable future for all of us.

Keywords: construction, demolition and excavation wastes, legislation, civil engineering works, Greece, Cyprus

1. Introduction/ problem

In the context of the Framework Contract on the Sustainable Management of Resources, the European Countries are conducting studies, in order to gain necessary knowledge regarding the current use of natural resources and especially wastes that can be used as alternatives to the first ones, towards sustainable development. This will be the basis for the development of future European policies in the area of sustainable resource management. According to the Waste Framework Directive 2008/98/EC, the term 'waste' is defined as any substance or object which the holder discards or intends or is required to discard.

Construction, demolition and excavation (CD&E) wastes consist of the debris generated during the construction, renovation, and demolition of buildings, roads, and other engineering works (fig.1). The large amounts of those wastes that are generated annually can be recycled and re-used because of the high potential for reuse and recycling embodied in these materials.

Figure 1. Deposit of CD&E Wastes in Western Macedonia, Greece

More particular, CD&E Wastes refer to a wide range of materials, which, according to their origin can be divided into the following categories:

- Demolition materials such as concrete, aggregates, wood, bricks and other building materials.
- Road materials such as bituminous mixtures as well as aggregates of various particle sizes.
- Excavation materials, such as excavated soil, sand, gravel, rocks etc, which arise almost in every construction activity, especially during the underground constructions and geotechnical engineering works.

Construction and Demolition Wastes are usually grouped together under "C&D Wastes"; however these waste streams are produced by different processes, while they have quite different characteristics, both in terms of quantities, composition and potential for recovery. Construction waste (originating from new constructions) is usually less mixed, less contaminated, and its recovery potential is higher than demolition waste because of these characteristics. Its share in the total quantities of C&D waste is generally low. On the other hand, demolition waste, which represents the highest amounts of C&D waste, tends to be more contaminated and mixed, and therefore is more difficult to recover.

Volume of CD&E Wastes produced depends on factors, main of which are population growth, city or regional planning, state of construction industry as well as landfill fees. Moreover, other factors include 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), the types of materials used in construction shows great regional variation (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.), cultural issues (e.g. demolition is seen as a failure in countries such as France, whereas it is regarded in a more positive way in other countries), or technical issues (the quality of the materials used in old construction influences the rate of demolition, e.g. more demolition is expected in new Member State because of the low quality of the concrete used in old constructions) [1].

Quantities of such wastes are enormous, this is why, worldwide, governments and municipalities try to follow legislation issued that encourages the reuse and recycling of those wastes in various applications.
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 and consists of numerous materials, including concrete, bricks, gypsum, wood, glass, metals, plastic, solvents, asbestos and excavated soil, many of which can be recycled. ETC/SCP working paper – Present recycling levels of Municipal Waste and C&D Waste in the EU, published in April 2009 [ETC/RWM 2009], gives estimates of per capita generation levels in all MS, with the exception of Romania and Slovenia- Table 1-. These figures are based on EUROSTAT data, completed by national reporting. The reference year is 2004.

Table 1 – C&D Waste arising per capita and added value of the construction sector [1]

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
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**

According to data, six countries (Denmark, Finland, France, Germany, Ireland and Luxembourg) report high quantities of C&D waste generation (over 2 tons per year per capita). Seven countries (Bulgaria, Greece, Hungary, Latvia, Lithuania, Poland and Slovakia) report very low levels of C&D waste generation (below 500 kg per year per capita).

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.

Two recent sources (UBA 2009 & ETC/RWM 2009) provide recycling and recovery rates of C&D waste in some MS. Both sources are based on national reporting, through either EUROSTAT or individual questionnaires sent to MS. There are important differences between these two sources, both on quantities of C&D waste arising and reported recycling rates. These differences are again due to several inconsistencies in the perimeter and definition of C&D waste. Some figures include excavated material while some others do not (for example, Germany generates 73 million tons of C&D waste without excavation soil [UBA 2008] and 192 million tones with excavation soil [1]. Likewise, some figures include waste from public works, while some others do not (for example, France generated 47.9 million tons of C&D waste from buildings, and this figure amounts to 343 million tons when waste from public work – which also includes a large part of excavation material – is included [UBA 2008]. Overall, it seems very difficult to calculate recycling rates for C&D waste in Europe.

Table 2 shows an attempt to correct these different biases by:

- Considering the corrected quantities arising: to avoid the overweighting of countries that include excavation waste in their reporting, and to correct the probable underestimations of quantities in countries with incomplete reporting.
- Using the most recent recycling rates reported in ETC/RWM by default, and UBA 2009 when missing: although these rates may or may not be including excavated material, it is assumed that the overall recycling rates reflect in any case the situation in a given country.
- Assuming a worst case scenario for countries where data is missing in both studies (i.e. 0% recycling rates/ N/A): countries with low reporting are assumed to also have low control, and therefore low recycling rates, for C&D waste.

Table 2 - Calculation of the average recycling rate of C&D waste (BIOIS, based on own assumption and data reported by ETC/RWM 2009 and UBA 2008, or individual estimations)

Country	Arising modified (TONS/CAPITA)	% re-used/ recycling
Austria	6,6	60%
Belgium	11,02	68%
Bulgaria**	7,8	0
Cyprus**	0,73	1
Czech Republic**	14,7	23
Denmark**	5,27	94
Estonia	1,51	92
Finland**	5,21	26
France**	85,65	45
Germany**	72,4	86
Greece**	11,04	5*
Hungary**	10,12	16
Ireland**	2,54	80
Italy	46,31	N/A
Latvia**	2,32	46
Lithuania**	3,45	60
Luxembourg**	0,67	46*
Malta	0,8	N/A

Netherlands	23,9	98
Norway	N/A	N/A
Poland**	38,19	28
Portugal	11,42	5*
Romania**	21,71	N/A
Slovak Republic**	5,38	N/A
Slovenia**	2	53*
Spain	31,34	14
Sweden	10,23	N/A
United Kingdom	99,1	75
EU27	**531,38**	**46**

*: UBA 2009

**: data from ETC/RWM 2009 corrected to exclude excavated material and fill data gaps

For 2011, recycling percentage differs significantly between the European countries and ranges between <10-90%. There are European countries such as Germany (~85%), Denmark (~90%), United Kingdom (~75%), Belgium(~60%), with high recycling rates, which have also developed technical knowhow, while there are countries such as Spain, Poland, Greece and Cyprus, where currently recycling rates are too low (Eurostat).

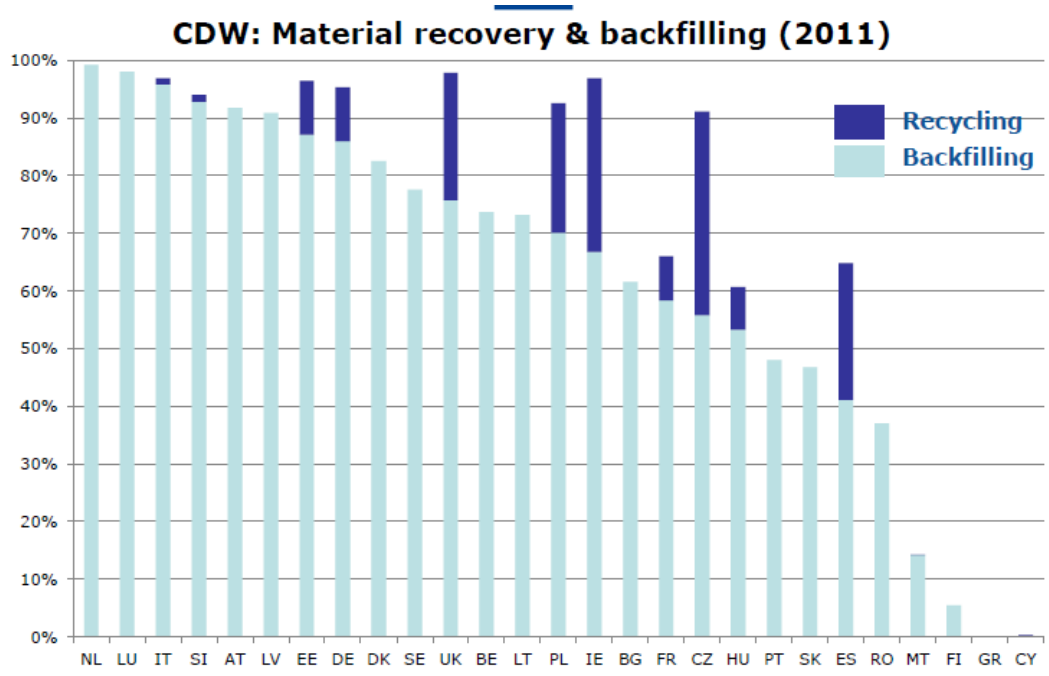

Figure 2. Material recovery and backfilling (2011)

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

In Europe, the Waste Framework Directive (WFD- Directive 2006/12/EC revised by Directive 2008/98/EC) requires Member States (MS) to take any necessary measures in order to achieve a minimum target of 70% (by weight) of C&D waste by 2020 for preparation for re-use, recycling and other material recovery, including backfilling operations using non hazardous C&D waste to substitute other materials. The amount of the recycling target is high enough to demand for the finding of alternatives to landfilling techniques, in order that those materials are reused or recycled. So, given the fact that construction and demolition waste has a high potential for recycling and re-use, since some of its components have a high resource value, their utilization especially in civil engineering works has potential since worldwide researches, up to date, certify it.

Current paper provides a comprehensive overview of current framework and utilization methods for reusing and recycling construction, demolition and excavation waste material in Europe and especially in Greece and Cyprus. Its structure consists of two main parts; one is dealing with current situation in Greece, while the second one with that in Cyprus. Main purpose of the paper is not only the monitoring of data related to CD&E Wastes' utilization but also a comparison which is made between the two European countries.

2. Construction and Demolition Wastes in Greece

2.1 General information

The term "Construction, Demolition and Excavation Wastes" according to European Waste Catalogue under code 17 00 00 is widely used to describe a large number of wastes generated from the construction and demolition of buildings and civil infrastructure, even after technical and physical disasters such as floods, earthquakes etc. In particular Construction wastes are off-cuts from new construction materials, while demolition ones are usually worn and modified from their original state. Worldwide, it has until recently been cheapest to landfill all CD&E Wastes, however during the last years, many regions have seen the development of several factors- such as the arrival of many landfills at full capacity or public resistance to the construction of local landfills, which when combined together, have made land filling undesirable. As far as C&D Wastes- apart from excavation ones- is concerned, their indicative composition is showed in figure 3[2].

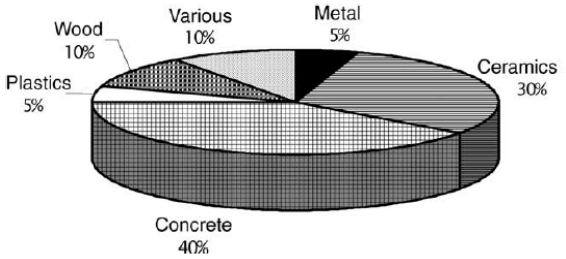

Figure 3. Indicative composition (%) of C&D Wastes

Before any prevention measurements, there are some points that need attention. Those points are:

- The description for each identified fraction the applications that are made in the construction sector (buildings and civil engineering),
- the amounts of waste that are generated,
- the composition of the waste stream,
- the treatment options in place,
- the current re-use and recycling rates already achieved, as well as
- the emerging techniques.

Unfortunately, there are not available detailed data concerning the exact amount of C & D waste generation, but just estimations, especially based on construction and demolition licenses. So, given this fact as well as that large quantities, especially of C&D Wastes, are often illegally deposited in various places all around Greece and that the construction companies were not obliged to monitor and report the quantitative characteristics of their wastes in a collective legal system until 2010, an estimation of their quantities is showed in Table 3.

Table 3. Total estimated quantities of C&D Wastes, (excluded excavation waste) for the years 1996-2000, 2004, 2006 and 2008 in Greece [3,4]

Year	Quantities of C&D Wastes (tons)
1996	1636298
1997	2006625
1998	2130939
1999	1899075
2000	2092387
2004	3324000
2006	6829161
2008	6828051

As a result, the effect of various waste prevention measures in this sector is characterized by uncertainty and is also difficult to be quantified.

2.2 Legal framework in Greece

One of the priorities of the European Commission and in particular of the "Europe 2020" is the sustainable development of low-carbon and resources-efficiency. The strategy therefore aims to prevent waste and promote reuse, recycling and recovery with the ultimate aim of reducing negative environmental impacts. The transition to a recycling society at a European level is an essential component of sustainable dimension of development focused on the protection of the environment, the support of economic production and the development and the achievement of the objective of sustainable cities.

Up to date legislation in Greece includes the following: European Directive 98-EE-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). However, the program for the management of C&D waste was put in place with the Joint Ministerial Decision 36259/1757/E103 (Gov. Gazzete, second issue, 1312/24.8.2010) in 2010. Present Gazzatte has specific quantitative targets, concerning the recycling and reuse of CD&E Wastes [5]. Those targets are summarized below:

1) By 2012, the preparing for reuse, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be increased to a minimum of 30 % by weight.

2) By 2015, the preparing for reuse, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be increased to a minimum of 50 % by weight.

3) By 2020, the preparing for reuse, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be increased to a minimum of 70 % by weight.

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.

C&D Wastes' management cannot be only a subject of technical and scientific process but also political, social and educational ones. In order to implement recycling targets, Greece created the term Alternative Waste Management and founded the National Organization for the Alternative Management of Packaging and Other Products, which later was renamed at "Greek Recycling Organization".

The alternative management of Construction and Demolition (C&D) Wastes in Greece began in 2011 with the 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 by the existing in 2012 was more than 12.000tons*, for 2013 around 50.000tn, while for 2014 more than 20.000tons* (*: data only from treatment plant "Anakyklwsis Adranwn Makedonias SA"). 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.

Recycling of C&D Wastes and the use of their, after treatment, products apart from the environmental benefits due to the restriction of the use of primary materials as well as the illegal and uncontrolled deposition in open spaces, has also economic benefits. Initially new jobs created both in the part of management and research on these materials. Secondly, it is crucial the fact that a supplier of C&D Wastes can take back pure secondary material at the same time he goes to the treatment plant, without being forced to go to the quarry. So the benefits have to do with both time and money savings.

The management costs range from 2,00 € -25,00 €/tn depending on the purity of the materials carried to the treatment plant including separation of various categories of wastes and their treatment till final product, which can be purchased at half the cost of a primary quarry material (an average of 3€/tn).

2.3 Possible uses of Recycled Aggregates

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.

As secondary aggregates in concrete mixtures materials used can originated from inert brick, aggregate mining, demolition aggregates, slag etc. Also, large amounts of concrete can be recovered from road, bridges' and foundations' demolition, and processed to be used in road construction, construction of pavements and replacing of gravel.
Products exported from the treatment of inert waste can be used with corresponding savings in raw materials in various categories of technical works, such as highways, sidewalks and similar projects. Main attention is given to fossil fraction (mineral materials), which is the largest. After advanced separation processes, recycled aggregates can be used in a wide range of applications, as follows:

- secondary bituminous binder
- mixture for the production of bricks
- mixture for the production of cement clinker
- mixture for the production of concrete
- base or sub-base
- as sealant or coating in Landfills as well as
- Generally wherever aggregates and sand are required.

All these materials can be processed, recycled and reused in various applications. The Collective Alternative Management System of CD&E Waste «Recycling Northern Greece SA " which is the first approved system in Greece in cooperation with the units contracted, sell the secondary material after it has been treated mainly as backfill material. However, this does not mean that the properties of recycled aggregates are inferior to the ones of primary natural aggregates and that they cannot be used in concrete production or road construction after the appropriate examination of their properties.

2.4 Studies concerning recycling of C&D Wastes in Greece (AUTh and DUTh)

C&D Wastes can be reused or recycled in many sectors, one of which is in civil engineering works. Those wastes, after the appropriate treatment, can be used as secondary materials for the production of new concrete mixtures, as base or sub base in road construction, as aggregates for the production of bituminous mixtures or as secondary filling material in geotechnical works. In Greece, and especially in the Universities of Thessaloniki and Thrace, recycled aggregates (REC) have been used for the production of new concrete mixtures. C&D Waste's composition is not steady, while there is no CE for those materials, so since they generate from building of different age, different concrete category etc utilization of those materials in civil engineering works and especially in concrete and road works demands every time laboratory tests in order to certify their use as alternative aggregates.
Main problem of REC has to do with the increased water absorption, which is due to the cement paste attached in recycled aggregate's surface. This fact results in decreased mechanical strength since for specific ratio w/c, rec absorb significant water content, so cement's hydration is limited [6-9].
More specifically, in Laboratory 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 [10]. Concrete mixtures have been produced at *central Laboratory for Quality Testing of ΑΕΓΕΚ* (member of the Joint Venture of Civil Engineering Works for the construction of METRO of Thessaloniki), while tests have been taken place at the above lab as well as the Laboratory of Building Materials of the Department of Civil Engineering of Aristotle University of Thessaloniki and Laboratory of Public Works of Central Macedonia according to relevant Specifications.
Properties examined included qualitative control of REC, as well as concrete's mixtures' characteristics such as workability, air voids as well as properties in hardened state such as mechanical strength, resistance to high temperatures and stereoscopic examination. According to laboratory results:

- 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).
- A decrease in workability, an increase in air voids, as well as a decrease in mechanical strength has been monitored.
- Concrete mixture with recycled coarse aggregates and natural fines was found to have a relatively higher compressive strength compared to conventional one, the one with no recycled aggregates (49.35MPa compared to 47.05MPa), which indicate that the use, mainly of coarse aggregates, has potential and can lead to mixtures with satisfactory characteristics and similar to the ones of mixtures with natural aggregates.
- Stereoscopic examination showed satisfactory bonding between recycled aggregates and the rest of the mixture, leading to satisfactory mechanical strength.
- Exposure to high temperatures resulted in a reduction in compressive strength and dynamic modulus of elasticity, while no surface crackings are noticed.
- Skid resistance was almost the same for all the mixtures (with REC or natural aggregates).
- 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€.

Following, research has been oriented to self compacted concrete, a special type of concrete, the use of which leads to the characteristics below:

- 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 (figure 4).

Figure 4. Surface made by SCC
Source: http://www.concretenetwork.com/photo-gallery/site_26/lafarge_18102/

- Homogeneous and uniform concrete.

In Greece, some examples of uses of SCC are:

- *silos for TITAN SA in Patras,*
- *Bridge of Rio-Antirio-Patras,*
- *Treasury of Bank of Greece in Thessaloniki,*
- *Metro of Thessaloniki etc*

In this case, recycled sand has substituted natural one in various percentages which ranged from 0 to 60% [7,11] Concrete mixtures have been produced at central Laboratory for Quality Testing of ΑΕΓΕΚ (member of the Joint Venture of Civil Engineering Works for the construction of METRO of Thessaloniki), while tests have been taken place at the above lab as well as the Laboratory of Building Materials of the Department of Civil Engineering of Aristotle University of Thessaloniki according to relevant Specifications. Fines percentage to the total mix came up to 60%, while coarse ones at 40%. Properties examined included rheological characteristics of the mixtures such as slump flow,

L-box, Vfunnel and air content. Mechanical characteristics remained practically unchangeable for replacement of natural sand by recycled one, up to 20%. 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€. Finally, optimum percentage of substitution was 30% w/t of the aggregates (fine and coarse ones) while compressive strength came up to 28,48MPa.
In parallel, during a master thesis in Democritus University of Thrace, light transmitting concrete with recycled aggregates has been examined. 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 [12].

3 Construction and Demolition Wastes in Cyprus [13-17]

3.1 General information

The lack of data, statistics and measurements related to C&D waste, the general difficulty that exists in the organization and monitoring of a recording system lacking a central receiver, as well as the experience of other countries where the amounts proposed are uncertain as well often with contradictory data, makes C&D waste quantification also in Cyprus difficult. For this reason, data of the statistical service of Cyprus have been used in combination with the CD&E waste calculation model that has been developed by the Unit of Environmental Science and Technology of the Department of Chemical Engineering of National Technical University of Athens, in order to make an estimate of the amount of waste. The establishment and adjustment of the assumptions that can be made on the basis of existing data that follow feature in many places the element of subjectivity. The estimated amounts of CD&E waste in Cyprus can be compared to the quantities that arise when the C&D waste production index is used. This index is proposed by the last study carried out on behalf of the Committee on the Environment DG ENV of the EU, (i.e. from 0.63 to 1.48 for construction and demolition waste, respectively and from 2.74 to 5.9tn/capita). Relative parametric increase of produced quantities of C&D waste due to increased tourism and coverage of needs, which consequently arises, can also be considered. So assuming that these C&D waste quantity indicators are applied, quantity of CD&E waste of Cyprus would be around 2.361.910 tons/annum to 5.085.865 tons/annum on the basis of the population of 862.011 inhabitants for 2012.
As already mentioned there are no reliable quantities available for C&D waste in Cyprus. Nevertheless, the 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.
The data collected for use in the calculations of the model are the following:

Table 3. Number of New Permits

YEARS										
2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
8.252	***9.098***	***9.794***	***9.521***	***8.896***	***8.950***	***8.777***	***7.506***	***7,172***	***5.341***	***0***

Table 4. Total produced C&D Wastes in Cyprus(tn) as calculated according to NTUA's model

PRODUCED WASTES								
	2008	2009	2010	2011	2012	2013	2014	**Average**
Construction	442.693	376.375	350.149	269.275	179.984	148.532	0	**308.488**
Demolition	226.440	0	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	0	**5.301.355**
TOTAL	**6.896.333**	**6.641.375**	**6.494.049**	**5.523.475**	**5.200.384**	**3.887.232**	**0**	**5.672.961**

3.2 Legal framework in Cyprus

The EU Solid Waste Management (SWM) Policy is defined and determined through an, continuously revised, institutional legislation complex. Through this, EU is trying to reach out the best possible approach for the complicated subject of SWM.

The basic principles supporting Community policy are:

- The "polluter pays", and
- «producer's responsibility»

In 2008, the community voted the EC 98/2008 on waste which defined the framework and the hierarchy in waste management as follows:

a) prevention,
b) preparing for re-use,
c) recycling,
d) other recovery, e.g. energy recovery, and finally
e) disposal.

The Community also introduced the Enlarged 'producer responsibility':

- "In order to strengthen prevention, reuse, recycling and other forms of recovery of waste, Member States may take legislative and non-legislative measures to ensure that natural or legal persons whose occupation is to develop, manufacture, process, route, sell or import products (producer of the product) have extended producer responsibility."
- Moreover, a minimum separate collection streams is introduced. This refers to the following materials: paper, metal, plastic and glass".

Specifically: "For the achievement of the objectives of this directive and the transition to a European recycling society with a high level of resource efficiency, Member States shall take the necessary measures to ensure the achievement of the following objectives [17].

a) by 2015, the preparing for re-use and recycling of waste materials such as at least: paper, metal, plastic and glass from households and possibly from other sources to the extent that such waste is similar to waste from households, shall be increased to a minimum of 50% of the total weight;

b) by 2020, the preparing for re-use, recycling and other material recovery, including landfill where work is done using waste to substitute other materials, of non-hazardous construction and demolition waste excluding naturally occurring material and defined in category 17 05 04 in the list of waste shall be increased by at least 70% of the weight. "

The Cypriot environmental legislation is under continuous development and harmonization with Community legislation, with the aim of drawing up a comprehensive framework of environmental policy and the adoption of laws and regulations on waste management in order to protect the environment and public health.

The Law 215 (I)/2002 (the Solid and hazardous waste Act of 2002) which applied for the management of solid and hazardous waste was replaced by the Law on waste N. 189/2011 harmonizing Cypriot law with EC 98/2008 of the European Parliament and the Council on 19th of November 2008 on waste.

From 29/10/2011, the regulations for management of construction and demolition Waste Excavating Law (ΚΔΠ 159/2011), are being applied under which the "producer responsibility" for waste Excavating construction and demolition waste is documented. The regulations apply to the owners and legitimate contractors of projects and make mandatory the carriage and handling of CD&E waste in suitable Processing Units. Even today, after the authorization of the two processing units (1) SKYRA VASSAS and (2) SKYRA LIMA (licensed from 22/5/2012-13/5/2017), and the "individual" and "collective" "systems", the current practice is the discarding in illegal and largely uncontrollable sites.

The regulations for C&D WASTE are still in a transition phase while partial implementation has begun. For this reason and by using the results of the statistical model for quantifying CD&E waste, NTUA's calculation model or the indicators proposed by the European Commission study of the quantity of waste, CD&E waste must be for the last ten years between 2.361.910 tn/year and 7.366.608 tn/year with a downward trend in recent years due to the financial crisis. The amount of CD&E waste that arrived at the processing plant SKYRA VASSAS for 2012 was 21.001ton, while for SKYRA LIMA for the time period 5/2012-12/2012 came up to 20477310tons and for 1/2013 till 5/2013 it came up to 6252682tons [18].

From empirical evidence on the operation of mobile crushers in Cyprus, given an average process of about 1,000 tn/year each and since two thirds of these are in operation, it seems that around 50,000 tn/year of C&D waste are being processed, mostly in parking lots. That is about 1.2% to 2.0% of the total estimated quantity produced nationwide.

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.

The gate fee for C&D (mixed debris) at the treatment units in Cyprus exceeds the 30 euros per ton. The prices of the treated aggregates depending on the screening and the quality may fluctuate from 2 to 5 euros per ton.
In Cyprus, apparently from the detailed description of the life-cycle of waste from excavation, construction and demolition waste, the appropriate environmental management of such wastes takes place in only a small proportion of the total CD&E wastes produced. In this direction three companies have gotten environmental permits and have approved EIAs for the establishment and development of fixed C&D waste processing units. Moreover, license for collection, transport and on-site management on construction sites (excluding the operation of the parking spaces, which characterize current situation) of waste of this category have acquired over 70 companies that have in their possession skip containers, or mobile crushers or mobile Screeners licensed by Advisory Committee on Waste Management and the Ministry of Interior Affairs. Most of these companies operate and perform tasks “Recycling” and treatment of CD&E wastes in approved parking spaces and cause distortion and damage to businesses that have invested in the licensing and construction of C&D waste processing units.
These quantities represent a significant portion of C&D waste nevertheless most waste materials arising from construction and demolition waste are disposed of mainly mixed in rubbish dumps or in non-licensed premises (such as gorges, riverbeds, abandoned quarries, etc).

4 Conclusions- suggestions

Management issues of CD&E Wastes are relatively complicated. On one hand high availability of raw materials, on the other hand recent legislation on CD&E Wastes’ management which is almost unknown by many public organizations and construction people in the two countries examined, makes the problem more difficult to deal with.
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 CD&E Wastes. Up to date, target for 2015 has not been achieved, while satisfaction of next target for 2020 seems too far away. Furthermore, there is 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. According to UBA 2008 & ETC/RWM 2009, in Greece 4,1million tons of C&D Wastes generated during 2004, while for the same year in Cyprus this amount reached 0,4million tones, with a recycling ratio of 1%. In general, in both countries recycling rates are too low, even based on estimations examined in the main part of the paper.
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.
Towards this direction, 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 and returned to the life cycle of various cement / bituminous mixtures and as a result in the construction sector, it is understood that any delay in implementing the alternative Management Law of CD&E Wastes, is against natural resources, which still are being used at high rates. Furthermore, a high proportion of buildings, which are reaching the end of their life cycle and the demolition of which would result in even greater quantities of discarded CD&E Wastes must be taken into account, since they expect to increase significantly quantities of C&D Wastes. Up to date, researches in Greek universities certify the alternative management of CD&E Wastes in Civil Engineering works and especially in cement or bitumen mixtures with positive and environmentally friendly impacts.
Furthermore, production cost of REC is expected to fall when the market of recycled aggregates will be regulated and the recycling rate of C&D waste will raise making recycled aggregates cheaper.
Measures that can be taken in both countries include the followings:
1) Promotion of the use of CD&E Wastes in cement or asphalt or soil based products in a technical and environmentally integrated manner.
2) Significant reduction in the amounts of CD&E Wastes especially through their use as replacements for natural aggregates at satisfactory rates.
3) Development and implementation of pilot applications of specific alternative management proposals of CD&E Wastes in Civil Engineering works.
4) Recording of existing positive knowledge and their integration into the Greek and Cypriot reality.
5) Dissemination of experience and knowledge to other professionals in order to achieve optimal integration of these practices in our country.
6) Indirect support and development of recycling industries and CD&E Wastes management.

This will achieve environmental protection through recycling / reuse of solid waste to be used as replacements of natural resources.

References

1. BIO Intelligence Service, European Commission (DG ENV), A project under the framework contract ENV G 4/FRA/2008/0112, Service contract on management of construction and demolition waste- SR1, Final Report task 2, February (2011)
2. Oikonomou N.: Recycled Concrete Aggregates, Cement & Concrete Composites, 27, 315–318, (2005).
3. Fatta, D. A Papadopoulos, Avramikos E., Sgourou E., Moustakas K., Kourmoussis F.Mentzis A. and Loizidou M.: Generation and management of Construction and Demolition waste in Greece- An existing challenge, Resources, Conservation and Recycling, Volume 40, 81-91, (2003).
4. http://ec.europa.eu/environment/waste/pdf/2011_CDW_Report.pdf, accessed 19 April 2015
5. http://www.ypeka.gr/LinkClick.aspx?fileticket=kzPoL7o5Zn8%3D&tabid=508, accessed 15 April 2015
6. Etxeberria M, E. Vazquez, A. Mari: Microstructure analysis of hardened recycled aggregate concrete, Mag Concr Res;58(10):683–90, (2006).
7. Savva A.: Concrete mixtures with recycled aggregates: effect of homogeneity of concrete of origin, Technical Chronical, Scientific Edition, (2009).
8. Mavridou, S. and N. Oikonomou: Experimental approach of using recycled aggregate from industrial processing in the production of new concrete, Part II, Electronic Proceeding of the 16th Concrete Conference, Paphos, Cyprus, (2009).
9. Mavridou S., N. Oikonomou and E. Kaisidou, “Utilization of construction and demolition wastes (C&D W) for the production of new concrete mixtures”, in abstract Proceedings of the CEMEPE/SECOTOX 2013 Conference, Mykonos, 24-29 June 2013.
10. http://anakyklosi-am.gr, accessed 15 April 2015
11. Gougoulias S., Konstantinidis G. and Manos L: Production of SCC by the use of recycled fines, Department of Civil Engineering, Aristotle University of Thessaloniki, (2011).
12. Mavridou S.: Light transmitting concrete with plastic optical fibres, Master Thesis, Laboratory of Building Materials, Department of Civil Engineering, Democritus University of Thrace, (2014).
13. Cypriot Democracy, Ministry of Agriculture, and Environment
14. Consulting Committee of Waste Management (ΣΕΔΑ)
15. http://www.skyravassas.com, accessed 15 April 2015
16. Cyprus Recycling Organization- http://www.oak.org.cy/, accessed 15 April 2015
17. http://europa.eu/rapid/press-release_IP-13-509_en.htm, accessed 15 April 2015
18. http://www.moa.gov.cy/moa/environment/environment.nsf/A8F973F9A5E92EEEC2257C24003AFC1C/$file/20130822.pdf, accessed 15 April 2015.