CAN CONCRETE BE GREEN IN BOSNIA AND HERZEGOVINA?

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SUMMARY

Bosnia and Herzegovina ratified the United Nations Framework Convention on Climate Change (UNFCCC) on May 17, 2000. The Kyoto Protocol was signed and ratified by the governments of 192 states and territories in the world. The Kyoto Protocol was ratified by Bosnia and Herzegovina on April 22, 2007, after completion of ratification procedures of all government levels. The First National Report of Bosnia and Herzegovina in accordance to the UNFCCC was issued in 2009 and the Second National Report of Bosnia and Herzegovina in accordance to the UNFCCC was adopted by B&H Council of Ministers in July 2013. The main goal of the Kyoto Protocol is to reduce greenhouse gas emissions to environment what caused many to focus on CO_2 emissions as the most critical environment impact indicator. Concrete is by far the most widely used construction material worldwide. One of its major components is Portland cement as a binder. Total production of cement in Bosnia and Herzegovina is about 850,000 tons in 2012, while fresh concrete production and concrete products amount approximately to 1,300,000 tons in 2012. Taking in consideration that production of every ton of cement yields to approximately 0.9 tons of CO_2 and every cubic meter of concrete contains about ten percent by weight of cement, significant quantity of CO_2 is produced by cement industry in Bosnia and Herzegovina. It is estimation in 2001, that cement industry emissions of CO_2 represented around 4 percent of total CO_2 emissions by energy and industry in Bosnia and Herzegovina. However, substituting significant amounts of cement in concrete mixture with industrial by-products such as silica fume, fly ash and blast furnace slag also leads to minimization of cement consumption, even producing more durable concrete. This paper discuss possibilities in decreasing CO_2 emissions in cement and concrete industry, as well as necessity of following directions of green and sustainable building in Bosnia and Herzegovina.

Key Words: CO_2 emission, cement, concrete, green buildings

1 Introduction

The essence of the Kyoto Protocol invites nations to commit themselves in reducing greenhouse gas (GHG) emissions. The Kyoto Protocol was adopted in Kyoto, Japan, December 11, 1997, but enacted or enforced on February 16, 2005. The goal of this protocol is to cope with the adverse effects of climate change, or global warming. The UNFCCC (United Nations Framework Convention on Climate Change), states the goal of the Kyoto Protocol is "*stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system*."

Many countries have agreed to legally bind limitations/reductions in their emissions of greenhouse gases, as part of the Kyoto Protocol. These binding limitations/reductions are tight in two commitments periods. The first commitment period is related to emissions between 2008-2012, and the second commitment period for emissions between 2013-2020.

The Kyoto Protocol considers emissions of six greenhouse gases:

- carbon dioxide (CO_2);
- methane (CH_4);
- nitrous oxide (N_2O);
- hydrofluorocarbons (HFCs);
- perfluorocarbons (PFCs);
- sulphur hexafluoride (SF_6).

There are 192 parties committed to the Kyoto Protocol. This includes 191 states (all the UN members except Andorra, Canada, South Sudan and the United States) and the European Union. The United States signed but did not ratify the Protocol. Canada withdrew from Protocol in 2011.

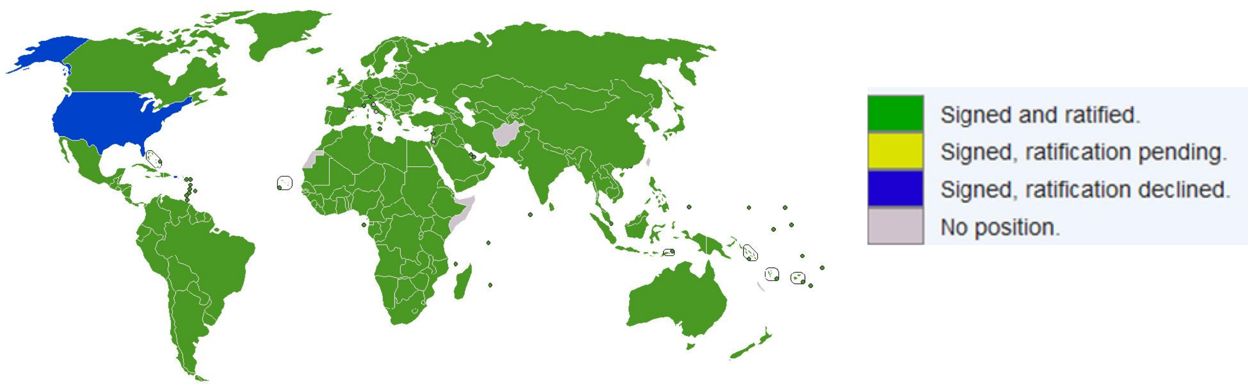

Figure 1 – Kyoto Protocol Participation

The Kyoto Protocol was ratified by Bosnia and Herzegovina on April 22, 2007, after completion of ratification procedures of all government levels. The First National Report of Bosnia and Herzegovina in accordance to the UNFCCC was issued in 2009 and the Second National Report of Bosnia and Herzegovina in accordance to the UNFCCC was adopted by B&H Council of Ministers in July 2013.

2. New Construction Paradigm

Construction industry is important part of the economy of each country. The old paradigm of construction took in consideration costs, schedule and quality. This paradigm was often presented as a triangle or a pyramid with cost supported by schedule and quality in each angle. This was very well known to each construction or project manager. There was attention in achieving the desired quality in a scheduled period of time for a minimal particular cost. New principles of green and sustainable approach to all aspects of human life introduced modifications of this paradigm in construction sector too. The Paradigm has changed and become much more comprehensive.

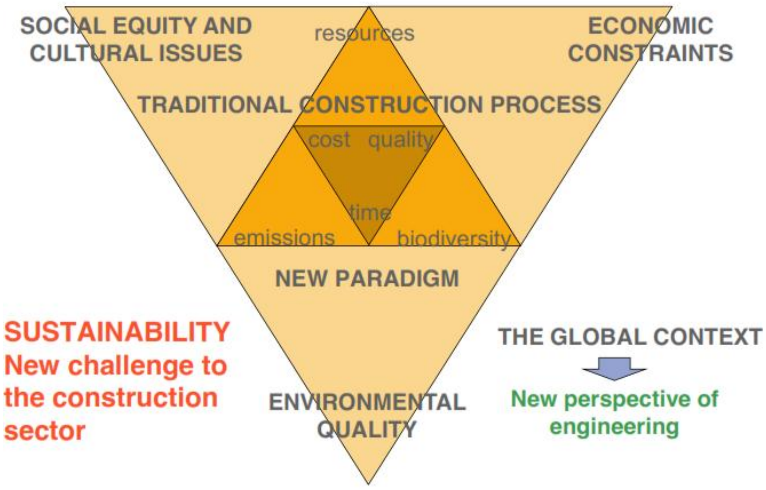

Figure 2 – New Construction Paradigm

The new paradigm involves additional factors beyond above mentioned. The decision making model in designing a project in order to achieve sustainability requires the balance of the old factors, plus human health, safety and comfort as it relates to the environment. Instead of a triangle or pyramid shape, depicting the decision model, the shape of the decision making model for sustainability construction looks like much more comprehensive.

The new EU Construction Products Regulation (CPR 305/2011/EU), published by the European Parliament on March 9, 2011, **completely replaced the Construction Products Directive (CPD 89/106/EEC) officially on July 1, 2013** and took in consideration this new approach. In its definitions, CPR 305/2011/EU defines construction product as any product or kit which is produced and placed on the market for incorporation in a permanent manner in construction works or parts thereof and the performance of which has an effect on the performance of the construction works with respect to the basic requirements for construction works. “Kit” means a construction product placed on the market by a single manufacturer as a set of at least two separate components that need to be put together to be incorporated in the construction works. CPR 305/2011/EU defines term “construction works” buildings and civil engineering works.

According to the CPR 305/2011/EU ANNEX I - Basic Requirements for Construction Works, Construction works as a whole and in their separate parts must be fit for their intended use, taking into account in particular the health and safety of persons involved throughout the life cycle of the works. Subject to normal maintenance, construction works must satisfy these basic requirements for construction works for an economically reasonable working life as follows:

1. *Mechanical resistance and stability*

The construction works must be designed and built in such a way that the loadings that are liable to act on them during their constructions and use will not lead to any of the following:

- ✓ collapse of the whole or part of the work;
- ✓ major deformations to an inadmissible degree;
- ✓ damage to other parts of the construction works or to fittings or installed equipment as a result of major deformation of the load-bearing construction;
- ✓ damage by an event to an extent disproportionate to the original cause.

2. Safety in case of fire

The construction works must be designed and built in such a way that in the event of an outbreak of fire:

- ✓ the load-bearing capacity of the construction can be assumed for a specific period of time;
- ✓ the generation and spread of fire and smoke within the construction works are limited;
- ✓ the spread of fire to neighboring construction works is limited;
- ✓ occupants can leave the construction works or be rescued by other means;
- ✓ the safety of rescue teams is taken into consideration.

3. Hygiene, health and the environment

The construction works must be designed and built in such a way that they will, throughout their life cycle, not be a threat to the hygiene or health and safety of workers, occupants or neighbors, nor have an exceedingly high impact, over their entire life cycle, on the environmental quality or on the climate during their construction, use and demolition, in particular as a result of any of the following:

- ✓ the giving-off of toxic gas;
- ✓ the emissions of dangerous substances, volatile organic compounds (VOC), greenhouse gases or dangerous particles into indoor or outdoor air;
- ✓ the emission of dangerous radiation;
- ✓ the release of dangerous substances into ground water, marine waters, surface waters or soil;
- ✓ the release of dangerous substances into drinking water or substances which have an otherwise negative impact on drinking water;
- ✓ faulty discharge of waste water, emission of flue gases or faulty disposal of solid or liquid waste;
- ✓ dampness in parts of the construction works or on surfaces within the construction works.

4. Safety and accessibility in use

The construction works must be designed and built in such a way that they do not present unacceptable risks of accidents or damage in service or in operation such as slipping, falling, collision, burns, electrocution, injury from explosion and burglaries. In particular, construction works must be designed and built taking into consideration accessibility and use for disabled persons.

5. Protection against noise

The construction works must be designed and built in such a way that noise perceived by the occupants or people nearby is kept to a level that will not threaten their health and will allow them to sleep, rest and work in satisfactory conditions.

6. Energy economy and heat retention

The construction works and their heating, cooling, lighting and ventilation installations must be designed and built in such a way that the amount of energy they require in use shall be low, when account is taken of the occupants and of the climatic conditions of the location. Construction works must also be energy-efficient, using as little energy as possible during their construction and dismantling.

7. Sustainable use of natural resources

The construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and in particular ensure the following:

- ✓ reuse or recyclability of the construction works, their materials and parts after demolition;
- ✓ durability of the construction works;
- ✓ use of environmentally compatible raw and secondary materials in the construction works.

While the parties will ultimately always consider the cost of the design in construction, they now have to take into account the human factors as well as the environment and how the ecology of the design relates to the overall environment.

Engineers and architects have choices of the material and products they use to design projects. Considering structure, the typical choice is among concrete, steel and wood. For roads and highways, the choice is generally between concrete and asphalt. Choice of the material depends on many factors including cost, characteristics, maintenance and performance for specific application. Today, engineers and architects are motivated more than ever before to select materials that are more sustainable due to increased interest in sustainable development. Discussing the term green building technology, it considers structures that are environmental friendly and resource-efficient throughout a building service life, from design to construction. Green approach to design of buildings assumes reducing overall impact on the natural environment by efficient use of energy, water and other resources as well as reducing waste, pollution and environmental degradation.

Right now it is assumed that about thirty percent of total CO_2 emissions in the world belong to the human activities related to the construction sector. The Tables 1 and 2 show total CO_2 emissions per sectors in twenty-seven EU countries in period 1990-2007.

CO2 Emissions* by Sector: EU-27
Million tonnes

	Total Energy:	Fuel Combustion:	-Energy Industries:	-Public Electricity and Heat Production	-Petroleum Refining	-Other Energy Industries	-Manufacturing and Construction:	-Iron and Steel	-Non-Ferrous Metals	-Chemicals	-Pulp, Paper and Print	-Food, Beverages and Tobacco	-Other	-Transport **	-Other Sectors:	-Commercial/Institutional	-Residential	-Agriculture/Forestry/Fisheries	-Other (Not elsewhere specified)	Fugitive Emissions from Fuels	Industrial Processes	Solvent and Other Product Use	Agriculture	Waste	Other	Total Emissions
1990	4082.9	4063.2	1671.6	1451.3	115.1	105.2	810.5	154.1	16.9	65.0	28.5	42.4	483.6	767.5	787.9	199.4	499.2	89.3	25.7	19.8	300.0	11.4		5.2		4399.5
1991	4055.9	4036.1	1647.6	1435.3	112.6	99.7	766.7	145.3	15.3	65.1	30.8	43.5	446.7	772.2	828.3	212.1	529.5	86.7	21.3	19.8	270.1	11.1		5.5		4342.6
1992	3916.3	3896.4	1570.6	1366.7	114.5	89.4	723.8	138.9	14.2	63.8	29.1	43.1	414.7	795.3	788.5	198.6	505.9	83.9	18.3	19.9	258.4	10.5		5.6		4190.7
1993	3864.1	3843.5	1509.3	1303.4	117.4	88.6	716.2	135.5	12.9	62.6	29.2	45.3	410.8	803.0	797.4	188.8	522.7	86.0	17.5	20.6	246.9	10.1		5.4		4126.4
1994	3824.1	3802.8	1507.8	1297.5	119.9	90.4	719.1	145.3	13.7	62.6	31.5	46.0	399.9	808.3	750.7	175.0	490.0	85.7	17.0	21.3	264.4	9.4		5.2		4103.1
1995	3859.7	3837.8	1505.6	1292.1	125.6	87.9	735.4	145.4	13.9	92.5	32.5	48.9	402.3	822.3	759.3	181.0	492.3	86.0	15.2	21.9	276.1	9.4		4.9		4150.2
1996	3972.0	3949.8	1533.2	1321.2	128.5	83.5	734.4	140.8	14.0	87.9	32.4	50.2	409.1	846.9	821.4	199.6	534.5	87.2	13.9	22.2	264.8	9.4		4.8		4251.0
1997	3874.6	3853.5	1481.6	1270.2	131.6	79.8	728.3	142.8	13.9	88.2	33.5	48.9	401.0	856.9	773.3	184.8	503.9	84.6	13.4	21.1	274.2	9.6		4.2		4162.6
1998	3868.6	3848.4	1496.5	1289.5	133.1	73.9	697.2	135.3	14.0	85.2	33.2	48.5	381.0	884.2	757.4	181.7	493.9	81.8	13.0	20.2	269.5	9.7		4.1		4151.9
1999	3811.4	3792.7	1455.4	1256.5	127.3	71.6	680.9	127.8	13.8	80.3	31.1	47.9	380.0	900.8	743.2	179.2	482.1	81.8	12.3	18.7	259.6	9.4		3.8		4084.3
2000	3820.9	3802.2	1486.6	1286.5	129.7	70.3	684.6	130.0	14.0	81.1	32.0	46.4	381.0	900.9	718.8	172.5	467.5	78.8	11.5	18.7	271.7	9.3		3.8		4105.8
2001	3908.3	3889.5	1519.8	1320.8	130.8	68.3	676.9	123.9	14.8	79.6	30.2	47.4	381.1	914.2	768.4	189.9	499.1	79.4	10.2	18.8	263.3	9.0		3.8		4184.4
2002	3880.8	3861.9	1541.2	1340.9	131.8	68.5	653.4	116.4	14.8	76.3	30.4	46.4	369.0	926.9	730.3	177.5	474.6	78.3	10.1	18.9	264.7	8.9		3.7		4158.1
2003	3970.1	3951.2	1583.1	1382.7	131.4	69.0	667.9	125.5	14.2	84.7	33.3	50.1	360.2	937.0	753.2	188.9	487.1	77.2	10.0	19.0	269.8	8.7		3.7		4252.3
2004	3972.2	3953.4	1574.2	1369.3	135.4	69.6	658.7	125.1	13.9	84.2	31.9	48.5	355.2	955.9	753.9	193.5	483.9	76.6	10.6	18.7	280.0	8.8		3.5		4264.4
2005	3935.2	3916.3	1569.9	1362.5	138.0	69.3	645.7	113.8	13.7	87.7	31.3	46.4	352.8	955.3	734.9	181.0	477.8	76.1	10.5	18.8	283.7	8.8		3.8		4231.5
2006	3938.4	3919.5	1578.1	1377.5	133.9	66.8	644.8	121.2	14.5	82.0	30.7	44.1	352.3	961.1	725.9	183.7	467.5	74.8	9.6	19.0	291.9	8.6		4.2		4243.1
2007	3873.6	3854.7	1597.4	1392.5	134.6	70.4	634.5	115.6	14.6	82.3	30.3	43.8	347.8	966.0	646.8	164.0	413.1	69.8	9.9	18.8	300.9	8.6		3.6		4186.7

Source: European Environment Agency (EEA), July 2009
* Excluding LULUCF (Land Use, Land – Use Change and Forestry) Emissions and International Bunkers
** Excluding International Bunkers (international traffic departing from the EU)
*** Emissions from Other (Not elsewhere specified), Fugitive Emissions from Fuels, Solvent and Other Product Use, Waste, Other
**** Emssions from Manufacturing and Construction and Industrial Processes
***** Emissions from Fuel Combustion in Agriculture/Forestry/Fisheries, Other (Not elsewhere specified), Fugitive Emissions from Fuels, Solvent and Other Product Use, Waste, Other

Table 1 - CO_2 emissions by sector in EU 27 in millions of tones

3. Concrete and Cement

Concrete is by far the most widely used construction material worldwide. In this regard, sustainable development of concrete and concrete design needs to be foundation of all construction activity in this millennium. For concrete production, the billions of tons of natural materials have been mined and processed worldwide and leave substantial mark on the environment. However, the most damaging aspect to the environment is huge quantity of energy used for production of Portland cement. In this process, large quantities of CO_2 are also released into atmosphere. So, cement and concrete may have an important role to play in enabling reducing the total CO_2 emissions from cement and concrete production.

CO2 Emissions* by Sector: EU-27
Shares %

	Total Energy:	Fuel Combustion:	-Energy Industries:	-Public Electricity and Heat Production	-Petroleum Refining	-Other Energy Industries	-Manufacturing and Construction:	-Iron and Steel	-Non-Ferrous Metals	-Chemicals	-Pulp, Paper and Print	-Food, Beverages and Tobacco	-Other	-Transport **	-Other Sectors:	-Commercial/Institutional	-Residential	-Agriculture/Forestry/Fisheries	-Other (Not elsewhere specified)	Fugitive Emissions from Fuels	Industrial Processes	Solvent and Other Product Use	Agriculture	Waste	Other	Total Emissions
1990	92.8	99.5	41.1	86.8	6.9	6.3	19.9	19.0	2.1	10.5	3.5	5.2	59.7	18.9	19.4	25.3	63.4	11.3	0.6	0.5	6.8	0.3		0.1		100
1991	93.4	99.5	40.8	87.1	6.8	6.1	19.0	18.9	2.0	11.1	4.0	5.7	58.3	19.1	20.5	25.6	63.9	10.5	0.5	0.5	6.2	0.3		0.1		100
1992	93.5	99.5	40.3	87.0	7.3	5.7	18.6	19.2	2.0	11.6	4.0	6.0	57.3	20.4	20.2	25.2	64.2	10.6	0.5	0.5	6.2	0.2		0.1		100
1993	93.6	99.5	39.3	86.4	7.8	5.9	18.6	18.9	1.8	11.5	4.1	6.3	57.3	20.9	20.7	23.7	65.5	10.8	0.5	0.5	6.0	0.2		0.1		100
1994	93.2	99.4	39.7	86.1	7.9	6.0	18.9	20.2	1.9	11.5	4.4	6.4	55.6	21.3	19.7	23.3	65.3	11.4	0.4	0.6	6.4	0.2		0.1		100
1995	93.0	99.4	39.2	85.8	8.3	5.8	19.2	19.8	1.9	12.6	4.4	6.7	54.7	21.4	19.8	23.8	64.8	11.3	0.4	0.6	6.7	0.2		0.1		100
1996	93.4	99.4	38.8	86.2	8.4	5.4	18.6	19.2	1.9	12.0	4.4	6.8	55.7	21.4	20.8	24.3	65.1	10.6	0.4	0.6	6.2	0.2		0.1		100
1997	93.1	99.5	38.4	85.7	8.9	5.4	18.9	19.6	1.9	12.1	4.6	6.7	55.1	22.2	20.1	23.9	65.2	10.9	0.3	0.5	6.6	0.2		0.1		100
1998	93.2	99.5	38.9	86.2	8.9	4.9	18.1	19.4	2.0	12.2	4.8	7.0	54.6	23.0	19.7	24.0	65.2	10.8	0.3	0.5	6.5	0.2		0.1		100
1999	93.3	99.5	38.4	86.3	8.7	4.9	18.0	18.8	2.0	11.8	4.6	7.0	55.8	23.8	19.6	24.1	64.9	11.0	0.3	0.5	6.4	0.2		0.1		100
2000	93.1	99.5	39.1	86.5	8.7	4.7	18.0	19.0	2.1	11.8	4.7	6.8	55.7	23.7	18.9	24.0	65.0	11.0	0.3	0.5	6.6	0.2		0.1		100
2001	93.4	99.5	39.1	86.9	8.6	4.5	17.4	18.3	2.2	11.8	4.5	7.0	56.3	23.5	19.8	24.7	65.0	10.3	0.3	0.5	6.3	0.2		0.1		100
2002	93.3	99.5	39.9	87.0	8.6	4.4	16.9	17.8	2.3	11.7	4.7	7.1	56.5	24.0	18.9	24.3	65.0	10.7	0.3	0.5	6.4	0.2		0.1		100
2003	93.4	99.5	40.1	87.3	8.3	4.4	16.9	18.8	2.1	12.7	5.0	7.5	53.9	23.7	19.1	25.1	64.7	10.3	0.3	0.5	6.3	0.2		0.1		100
2004	93.1	99.5	39.8	87.0	8.6	4.4	16.7	19.0	2.1	12.8	4.8	7.4	53.9	24.2	19.1	25.7	64.2	10.2	0.3	0.5	6.6	0.2		0.1		100
2005	93.0	99.5	40.1	86.8	8.8	4.4	16.5	17.6	2.1	13.6	4.8	7.2	54.6	24.4	18.8	24.6	65.0	10.4	0.3	0.5	6.7	0.2		0.1		100
2006	92.8	99.5	40.3	87.3	8.5	4.2	16.4	18.8	2.2	12.7	4.8	6.8	54.6	24.5	18.5	25.3	64.4	10.3	0.2	0.5	6.9	0.2		0.1		100
2007	92.5	99.5	41.4	87.2	8.4	4.4	16.5	18.2	2.3	13.0	4.8	6.9	54.8	25.1	16.8	25.3	63.9	10.8	0.3	0.5	7.2	0.2		0.1		100

Source: European Environment Agency (EEA), July 2009
* Excluding LULUCF (Land Use, Land – Use Change and Forestry) Emissions and International Bunkers
** Excluding International Bunkers (international traffic departing from the EU)

Table 2 - CO_2 emissions by sector in EU 27 in shares (%)

Though "cement" and "concrete" are often used interchangeably, concrete is actually the final product made from cement. The primary component of cement is limestone. To produce cement, limestone and other clay-like materials are heated in a kiln at 1400°C and then ground to form a lumpy, solid substance called clinker; clinker is then combined with gypsum to form cement.

Cement manufacturing is highly energy and emissions intensive because of the extreme heat required to produce it. Producing a ton of cement requires 4.7 million BTU of energy, equivalent to about 200 kilo of coal, and generates nearly a ton of CO_2. Given its high emissions and critical importance to society, cement is an obvious place to look to reduce greenhouse gas emissions.

A single industry of cement accounts for around five percent of global carbon dioxide (CO_2) emissions. It produces a material so ubiquitous it is nearly invisible: cement. Cement is the primary ingredient in concrete, which in turn forms the foundations and structures of the buildings we live and work in, and the roads and bridges we drive on. Concrete is the second most consumed substance on Earth after water. On average, each year, three tons of concrete are consumed by every person on the planet.

Concrete is used globally to build buildings, bridges, roads, runways, sidewalks, and dams. Cement is indispensable for construction activity, so it is tightly linked to the global economy. Cement production is growing by percent annually, and is expected to rise from 2.55 billion tons in 2006 to 3.7 - 4.4 billion tons by 2050.

The production of cement releases greenhouse gas emissions both directly and indirectly: the heating of limestone releases CO_2 directly, while the burning of fossil fuels to heat the kiln indirectly results in CO_2 emissions.

The direct emissions of cement occur through a chemical process called *calcination.* Calcination occurs when limestone, which is made of calcium carbonate, is heated, breaking down into calcium oxide and CO_2. This process accounts for approximately fifty percent of all emissions from cement production.

Indirect emissions are produced by burning fossil fuels to heat the kiln. Kilns are usually heated by coal, natural gas, or oil, and the combustion of these fuels produces additional CO_2 emissions, just as they would in producing electricity. This represents around forty percent of cement emissions. Finally, the electricity used to power additional plant machinery, and the final transportation of cement, represents another source of indirect emissions and account for five to ten percent of the industry's emissions.

According to the First and Second BIH National Reports according to the UNFCCC, cement production industry in BiH produces the biggest amount of CO_2 in industrial sector after the industry of steel and iron. It represents three percent of total CO_2 emission in BiH.

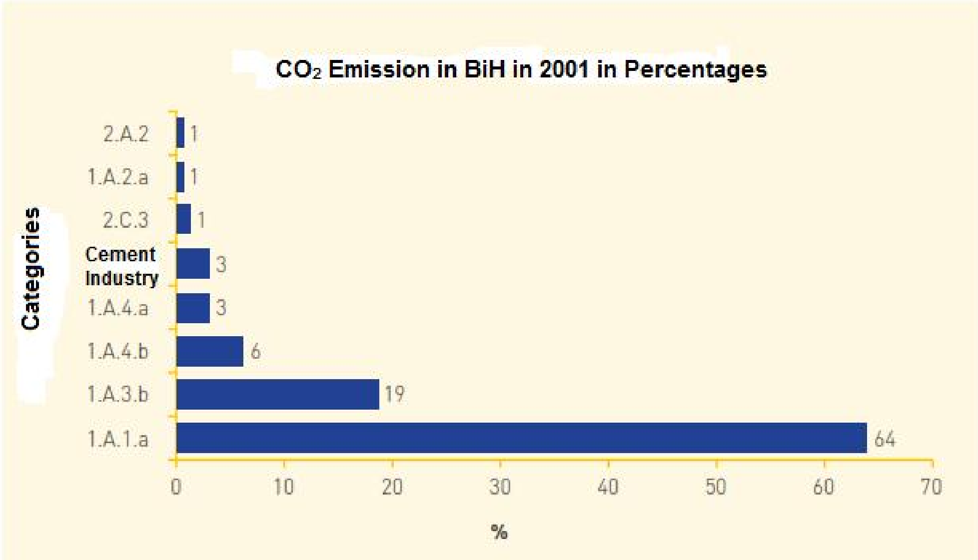

Figure 3 – CO_2 Emission in BiH in 2001

The following table shows the quantity of cement produced in BiH made according to the data by Thematic Reports on Industrial Production in BiH in years 2009-2012 by Agency for Statistics BiH.

Cement Production in BiH in Tonnes			
2009	**2010**	**2011**	**2012**
1,073,762	948,513	893,017	845,657

Table 3 - Cement Production in BiH 2009-2012

Table 4 is made based upon data from the same source as previous table and represents production of concrete in BiH in period 2009-2012.

	Concrete Production in BiH in Tonnes			
	2009	**2010**	**2011**	**2012**
Concrete Products	282,496	330,194	408,732	328,788
Fresh Concrete Mix	807,675	1,019,618	1,175,035	1,270,725
TOTAL	**1,090,171**	**1,349,812**	**1,583,767**	**1,599,513**

Table 4 - Concrete Production in BiH 2009-2012

Analyzing these two last tables, it is obvious that cement production in BiH is reduced in period 2009-2012 by twenty-one percent, while concrete and concrete products production increased by almost forty-seven percent, which is very interesting comparison. Most possibly, it is a result of cement import in BiH from neighboring countries, while increase in concrete production is result of intensified efforts in construction on Highway-Corridor Vc, in period of time considered. However, as much as such trends are favorable to emissions of CO_2, economical effects for economy of BiH are questionable. We will be happy to conclude that such trends are result of introducing green technologies in cement production, but unfortunately this was probably not a case.

4. Opportunities for Reducing CO_2 Emissions in Concrete Production in BiH

A primary goal is a reduction in use of Portland cement, which is possible to archive by partially replacing it with various cementitious materials. Most preferably are byproducts of different industrial processes in which way double goal is scored. One of such materials is fly ash, actually a residue of coal combustion which can be excellent substitution. The use of fly ash has a number of advantages but some disadvantages as well. Fly ash can improve specific properties of concrete, such as durability. The fly ash is less expensive than Portland cement and since it is a waste product, it should be disposed at great cost. However, there is a relatively slow rate of concrete strength development, but it is irrelevant in applications where high early strength is not required.

Another excellent cementitious material is ground granulated blast furnace slag. It is byproduct by steel industry. As fly ash, the ground granulated blast furnace slug can improve some mechanical and durability properties of concrete, while the cost of slag is comparable to Portland cement.

Replacing cement with silica fume which is a byproduct of semiconductor industry is additional option, although there is no such industry in Bosnia and Herzegovina. This siliceous material improves both strength and durability of concrete and it is already part of concrete mix for high strength concretes. The silica fume is difficult to handle due to its extreme fineness and is much more expensive than cement. It also reduces the concrete fire resistance.

The other aspect to make green concrete is substitution of virgin aggregate material with concrete debris, especially taking in consideration that vast amounts of material are needed for aggregate in concrete. Using such debris to produce new concrete conserves natural resources and reduces valuable landfill capacity at the same time.

Additional possibility is material excavated from the construction of tunnels such as current construction of the tunnels at the Highway Corridor Vc, which may very well be suitable as aggregate to produce concrete for tunnel lining. In absolute terms, it may render unnecessary mining of hundreds of thousand tons of virgin materials for concrete aggregate. According to findings of the author of this paper, it is currently done exactly on the construction of the Highway Corridor Vc.

Except the possibility discussed in last paragraph, Bosnia and Herzegovina did not do much about production of green concrete. However, further research developments abroad and in Bosnia and Herzegovina and different analysis should highlight the direction in reducing GHGs emissions in concrete and cement production, as well as other environmental aspects of the concrete production. So, the answer to the question from the title of this paper is not simple, but definite conclusion is – “concrete can be greener, than it is now”. This paper just highlights some possibilities and directions, but future research and analysis will provide the answer.

5. Conclusion

In general, the construction industry consumes forty percent of the total energy and about one half of the world's major resources. It is estimation that production of concrete produces seven percent of total CO_2 emissions in the world. Every one ton of cement produced, leads to about 0.9 tons of CO_2 emissions and typical cubic meter of concrete contains about ten percent of cement. In the other hand, available sources of suitable virgin aggregates are depleted and opening new sources of virgin materials is getting increasingly difficult, because of environmental concerns. The water requirements for concrete production in the world are almost four trillion liters of water each year worldwide, and this does not include wash water and curing water. So, the possibilities for production of green concrete in Bosnia and Herzegovina are more or less the same as in the other countries and lead in two major directions:

- Increased use of supplementary cementitious material, especially those that are byproducts of industrial processes; and
- Increased reliance on recycled materials. Since aggregate constitutes the bulk of concrete, en effective recycling strategy will lesson the demand for virgin materials and diminish landfill areas capacities.

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