Journal of Advances and Scholarly Researches in Allied Education

Vol. VI, Issue No. XI, July-2013, ISSN 2230-7540

AN INTERNATIONALLY INDEXED PEER REVIEWED & REFEREED JOURNAL

A COMPARATIVE STUDY ON SPECIALIZED AND ENVIRONMENTAL IMPACT EVALUATION OF CONCRETE PRODUCTS

Journal of Advances and Scholarly Researches in Allied Education
Vol. VI, Issue No. XI, July-2013, ISSN 2230-7540

A Comparative Study on Specialized and Environmental Impact Evaluation of Concrete Products

T. Dasappa

Research Scholar, Mahatma Jyotiba Phule Rohilkhand University, Barely, U.P.

Abstract – The cement and concrete industries are huge. What does this mean in terms of the environment? Concrete and other cementations materials have both environmental advantages and disadvantages.

Current environmental and economic circumstances accelerate the developments of new concrete constituents. Whereas the process technology impacts the mix-design strategy, it seems obvious that manufacturing process is prone to evolutions. This article presents a method to compare environmental and economic consequences of different technological solutions on the basis of the influence on the cement consumption needed for a given concrete performance. Case study is the choice of dry batch or central mixed concrete production systems for a ready mixed concrete production. The theoretical difference in cement consumption is estimated by considering that the water content fluctuation is by far the dominant factor governing the truck to truck variation. The addition of a mixer is effectively found to contribute to cement reduction. Environmental comparison is performed using an EADT indicator (Environmental Amortization Duration Time) defined in the article, and testing various environmental data. The EADT for energy consumption, released CO2 and particles are found below 6 years, in the whole range of tested environmental data for an annual production of 40,000 m3 yr_1, with 2 m3 mixer for the central mixed concrete plant. The NOx and SO2 EADT results are found sensitive to the releases of the steel plant. The financial amortization duration time corresponding to the purchase of a mixer, is found less than 2 years. Although the chosen application case is simplified, these results encourage further research.

Environmental impact of building products consists of procurement of raw material, manufacture items (raw materials and product) and also the use of energy resources during transportation – all of which burden the environment. Environmental burdens of concrete and concrete products consist of limestone quarrying, burning and grinding of clinker, extraction, excavation and crushing of cement stone materials, manufacturing and transportation of raw materials and the final product. The environmental burdens of concrete, hollow-core slabs, roofing tiles, exterior wall panels, concrete beams and columns are dealt with in the assessment.

The differences in environmental burdens between various concrete products are a consequence of different binder contents and types, long transportation distances of raw materials and products and different electricity consumption especially in the production phases. Environmental impacts in the material manufacturing and construction stages of a retaining wall using precast concrete with a revegetation function and a retaining wall placed in situ with ready-mixed concrete were compared. The retaining wall using precast concrete was constructed by piling hollow precast concrete boxes of which hollows were filled with soils emitted in the construction site.

---------------------------------x---------------------------------

INTRODUCTION

Concrete is a material used in building construction, consisting of a hard, chemically inert particular substance, known as an aggregate (usually made from different types of sand and gravel), that is bonded together by cement and water.

The Assyrians and Babylonians used clay as the bonding substance or

cement. The Egyptians used lime and gypsum cement. In 1756, British engineer, John Smeaton, made the first modern concrete (hydraulic cement) by adding pebbles as a coarse aggregate and mixing powered brick into the cement. In 1824, English inventor, Joseph Aspdin, invented Portland Cement, which has remained the dominant cement used in concrete production. Joseph Aspdin created the first true artificial cement by burning ground limestone and clay together. The burning process changed the chemical properties of the materials and Joseph Aspdin created stronger cement than that which uses plain crushed limestone would produce.

Cement production requires a source of calcium (usually limestone) and a source of silicon (such as clay or sand). Small amounts of bauxite and iron ore are added to provide specific properties. These raw materials are finely ground and mixed, then fell into a rotary cement kiln, which is the largest piece of moving industrial equipment in the world. The kiln is a long, sloping cylinder with zones that get progressively hotter up to about 1,480°C. The kiln rotates slowly to mix the contents moving through it (Fig. 1). In the kiln, the raw materials undergo complex chemical and physical changes required to make them able to react together through hydration. The most common type of cement kiln today is a dry process kiln, in which the ingredients are mixed dry. Many older kilns use the wet process.

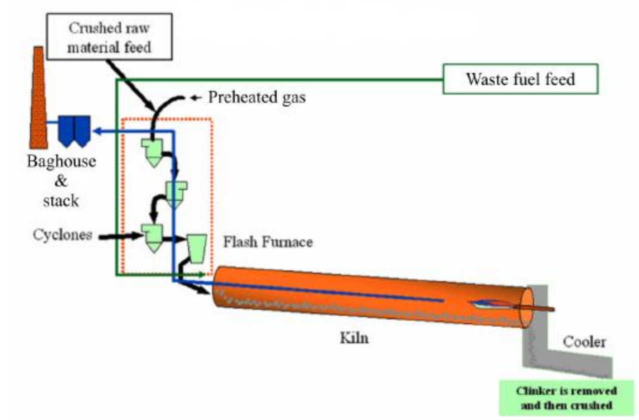

Fig. 1 – Cement kiln.

The first important reaction to occur is the calcining of limestone (calcium carbonate) into lime (calcium oxide) and carbon dioxide, which occurs in the lower-temperature portions of the kiln-up to about 900°C. The second reaction is the bonding of calcium oxide and silicates to form dicalcium and tricalcium silicates. Small amounts of tricalcium aluminate and tetracalcium aluminoferrite are also formed. The relative proportions of these four principal compounds determine the key properties of the resultant Portland cement and the type classification (Type I, Type II, etc.). These reactions occur at very high temperatures with the ingredients in molten form. As the new compounds cool, they solidify into solid pellet form called clinker. The clinker is then grounded to a fine powder, a small amount of gypsum is added, and the finished cement is bagged or shipped bulk to ready mix concrete plants.

However, environmental performances of concrete have only recently become a subject of concern. They are often improved by the incorporation of recycled industrial wastes in the mix-design, most recently (Polettini et al., 2009; Bashar and Nounu, 2008), without reducing the quality of the final product. Environmental impacts of cement production have been studied (Josa et al., 2007; Pade and Guimaraes, 2007; Huntzinger and Eatmon, 2009) because it requires high energy consumption and induces important greenhouse gas emissions. Whereas developments of new constituents of cement accelerate, cement concrete production processes are only prone to minor evolutions. However, the influence of the process characteristics on the concrete properties (and consequently on the concrete composition needed for a given certified characteristics) are widely recognized, either for high performance or common concretes. In this article, a method to compare environmental and economical consequences of different technological solutions on the basis of the influence on the cement consumption needed for a given concrete performance is presented. Case study is the choice of dry batch or central mixed concrete production systems. These two main processes of ready mix concrete production are compared, with the aimto advance in quantifying the difference in energy consumptions and greenhouse gas emissions.

CHARACTERIZATION AND WEIGHING OF THE ENVIRONMENTAL EFFECT

It is proposed that environmental properties of building products be divided into 2 classes: basic and energy raw materials. Each of these would have two classification options. Basic raw materials are either termed recycled or natural while energy raw materials can be renewable or non-renewable.

In order to limit the number of environmental parameters, the harmful emissions can be characterised and weighed as follows. The suggested procedure is mainly based on other references (Anon 1995) with more detailed reasoning presented elsewhere (Häkkinen and Kronlöf 1994). The characterisation and weighing of emissions having a potential affect on the ozone depletion or on nutrification are not dealt with. This is because house building does not significantly effect the nutrification with reference to its volume and because the Finnish building product industry has abandoned the use of aerosol propellants, which potentially affect the volume of the ozone layer. In the following analysis the ecotoxical and toxically compounds are also excluded because generally accepted methods for dealing with these emissions are still missing. Table 1 shows the computation rules for classified environmental effects.

GLOBAL WARMING	
Global Warming Potential (GWP) of gaseous compounds based on the reference list by IPCC (Inter-governmental Panel on Climate Change) (Houghton 1992) (100 year estimates): for example	
COMPOUND	WEIGHTING COEFFICIENT
CO_2	1
CH_4	25
ACIDIFICATION	
Acidification Potential (AP) is expressed in terms of the potential influence on the production of H^+-ions based on stoichiometric equations with reference to SO_2 (Heijungs et al. 1992): for example	
COMPOUND	WEIGHTING COEFFICIENT
SO_2	1.00
NO_X	0.70
PHOTOCHEMICAL FORMATION OF OXIDANTS (SMOG)	
The production of ozone by emission with reference to ethene is expressed by Photochemical Ozone Creation Potential, POCP (Anon 1991). Because of difficulties in evaluating the composition of VOCs, emissions are only divided into ethene, methane and others. The following potentials are employed:	
COMPOUND	WEIGHING COEFFICIENT
Ethene	1
Methane	0.01
Others	0.4

Table 1. Computation rules for classified environmental effects.

METHOD OF THE ENVIRONMENTAL IMPACT ASSESSMENT

An environmental impact assessment was performed using LIME whose evaluations are based on Japanese weather and the country's geographical conditions. The LIME method sets forth four objects of protection consisting of human health, public assets, biodiversity and primary production capacity, which have unique indexes consisting of DALY (Disability-Adjusted Life Year, unit: year), YEN (Japanese monetary unit, unit: yen), EINES (Expected Increase Numbers of Extinct Species, unit: species) and NPP (Net Primary Productivity, unit: t/ha/year), respectively (Kawai et al. 2005a).

The degree of environmental impact can be evaluated with these four indexes and furthermore with a single index that is an integrated index of these four indexes. In this case study, the manufacturing of materials, transportation of materials, construction, waste treatment, material recycling and change of land use were estimated. As environmental impact, the uses of oil, coal, natural gas, purchased electricity, nonmetallic minerals and iron and the emissions of CO2, SOX, NOX and particulate matter were estimated.

To evaluate the revegetation on the hollow blocks in Case-1, the followings are assumed based on categories of land use in LIME & 3: 1200 m2 of "forest" were changed to 360 m2 of "other groves" and 840 m2 of "road," and the land uses were maintained for 50 years. Regarding the construction works, the road construction work was adopted as the EINES damage factors of works, in this case study.

RAW MATERIAL USE

The raw materials used in cement production are widely available in great quantities. Limestone, marl, and chalk are the most common sources of calcium in cement (converted into lime through calcination). Common sources of silicon include clay, sand, and shale. Certain waste products, such as fly, can also be used as a silicon source. The iron and aluminum can be provided as iron ore and bauxite, but recycled metals can also be used. Finally, about 5% of cement by weight is gypsum, a common calcium- and sulfur-based mineral. It takes 1,455…1,597 kg of raw materials to produce one ton of finished cement, according to the Environmental Research Group at the University of British Columbia (UBC).

The water, sand and gravel or crushed stone used in concrete production in addition to cement are also abundant. With all of these raw materials, the distance and quality of the sources have a big impact on transportation energy use, water use for washing, and dust generation. Some aggregates that have been used in concrete production have turned out to be sources of radon gas. The worse problems were when uranium mine tailings were used as concrete aggregate, but some natural stone also emits radon.

Fly ash is a fine, glass-like powder recovered from gases created by coal-fired electric power generation. Power plants produce millions of tons of fly ash annually, which is usually dumped in landfills. Fly ash is an inexpensive replacement for Portland cement used in concrete, while it actually improves strength, segregation, and ease of pumping of the concrete. Fly ash is also used as an ingredient in brick, block, paving, and structural fills.

The use of fly ash from coal-fired power plants is beneficial in two ways: it can help with our solid waste problems, and it reduces overall energy use. While fly ash is sometimes used as a source of silica in cement production, a more common use is in concrete mixture as a substitute for some of the cement. Fly ash, or pozzolan, can readily be substituted for 15…35% of the cement in concrete mixes, and for some applications fly ash content can be up to 70%. Fly ash today accounts for about 9% of the cement mix in concrete. Fly ash reacts with any free lime left after the hydration to form calcium silicate hydrate, which is similar to the tricalcium and dicalcium silicates formed in cement curing. Through this process, fly ash increases concrete strength, improves sulfate resistance, decreases permeability, reduces the water ratio required, and improves the pumpability and workability of the concrete. Fly ash is widely used in Europe as a major ingredient in autoclaved cellular concrete (ACC); in the United States, North American Cellular Concrete is developing this technology.

CONCRETE PRODUCTION PROCESSES

Production variability : Concrete manufacturer needs to certify that concrete characteristics are respected in the most variable conditions. They should take into account that significant deviations in strength and flowability occurs during concrete production. These deviations come from:

- Constituents physical and chemical variability; most often the main effect is those of cement, but water, aggregates and admixture may also have significant effect;

- Process characteristics variation, like temperature, loading sequence, mixing time, transport duration.

- Mix-composition variability.

Several industrial studies e Day (1995) is one of the few published e indicate that the key variability reason is the water content inconstancy, largely before other fluctuations like chemical activity of cement or sand's fines content.

Main types of production process : Concrete production consists of mixing aggregates (sand and gravels), cement (and sometimes other fine elements), water and admixtures, and then molding the obtained mixture. Ready mixed concrete is manufactured in a concrete plant and transported to the building site by the use of truck mounted mixer.

Two main types of production systems are used for ready mixed concrete production. In the so called "central mixed concrete plant", ingredients are poured into a fixed mixer and mixed generally less than 1 min. The resulting mixture is poured into the truck mounted revolving mixer which performs only an additional mixing during transport. A concrete mixing truck volume is usually about 6e9 m3 and several batches are needed to fill it, as typical mixer's volume is 1 or 3 m3. Each batch respects the mix-design composition. However, current practice is to estimate water content in the mixed batch, for instance by using power consumption evolution. The plant operator uses this information to adjust the added water proportioning in the following batches. This method allows adjusting water content in the truck.

ENVIRONMENTAL BURDENS OF CONCRETE

The assessment of environmental burdens of concrete is based on the materials and energy flows reported by the Finnish material producers. The inventory principles followed in this study are in accordance with the ISO-proposal. In concrete manufacturing processes, including limestone quarrying, burning and grinding of clinker, extraction, excavation and crushing of stone materials, concrete manufacturing and transportation of raw materials and products, the environmental burdens which result are:

- using fossil fuels,

- using natural raw materials,

- using land,

- using energy and also from process emissions.

Figure 2 shows the concrete manufacturing process from the procurement of raw materials until demolition and recycling of the product. The environmental profile for a 1-kg concrete product (hollow-core slab) is shown in Table 2, excluding assembling, using, demolition and recycling.

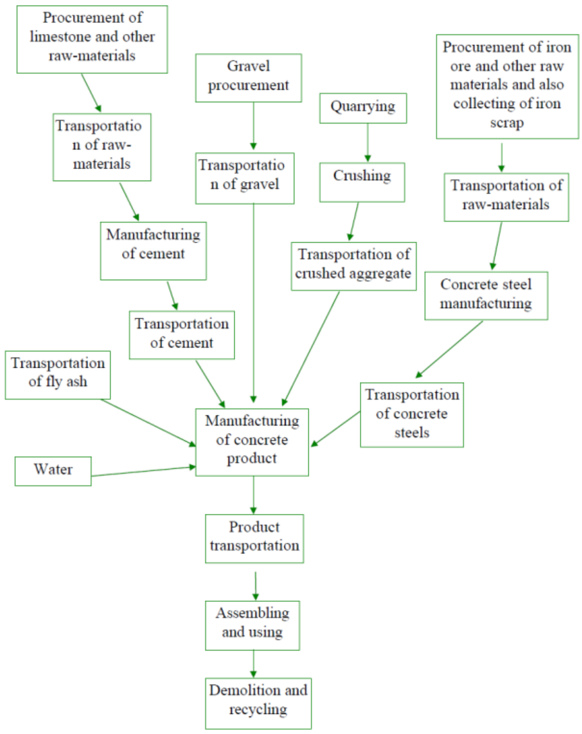

Figure 2. Life cycle of manufacturing process of steel reinforced concrete products.

Energy		
Fossil fuel *	0.93	MJ/kg product
Electricity **	0.20	MJ/kg product
Natural raw materials		
Limestone	170	g/kg product
Other mineral aggregates	850	g/kg product
Iron ore	0.014	g/kg product
Emissions		
Carbon dioxide, CO_2	120	g/kg product
Nitrogen oxide, NO_x	0.55	g/kg product
Sulphur oxide, SO_2	0.14	g/kg product
Methane, CH_4	0.13	g/kg product
Volatile organic compounds, VOC_{tot}	0.18	g/kg product
Dust	0.023	g/kg product
Heavy metals ***	20	μg/kg product

* In final use (combustion) and in procurement the energy raw materials presented with reference to higher heating value (HHV).
** In electricity production and in procurement energy presented with reference to higher heating value (HHV).
*** Heavy metals emissions into air are Cr, As, Cd, Hg, Tl and Pb.

Table 2. Environmental profile of steel reinforced concrete hollow-core slab.

The main portion of concrete is composed of natural raw materials and the environmental burdens are caused by land use, raw material procurement and energy use in the transportation and manufacturing processes.

CONCRETE

Cement and concrete are vital components in building construction today. Concrete has many environmental advantages, including durability, longevity, heat storage capability, and chemical inertia. In many situations concrete is superior to other materials such as wood and steel. But cement production is very energy intensive – cement is among the most energy intensive materials used in the construction industry and major contributor to CO2 in the atmosphere.

In spite of recent evolutions in control and dosage systems, concrete production processes tolerate obvious inaccuracies, particularly concerning the water dosage. Aggregates are naturally moistened and their water content has to be monitored to assess total water proportion into the mixture. At this stage, the study is limited to the ready mix concrete production. The cement consumption is compared between a dry batch plant and a central mixed plant.

These two main types of ready mixed concrete manufacturing processes have been compared from technical, environmental and economical point of views, on the basis of identical strength of the final product (hardened concrete). Comparison is performed on the basis of an annual production of 40,000 m3 yr_1. The additional mixer in a wet batch concrete plant is a 2 m^3 mixer.

To perform environmental and economical comparisons, a new environmental indicator, called EADT (Environmental Amortization Duration Time) was created. The environmental assessment was performed taking into account the variability range of Life Cycle Inventories data. The EADT for released CO2 and particles as well as energy consumption, are found below 6 years, in the whole range of tested environmental data. The NOx and SO2 EADT results are found sensitive to the releases of the steel plant. The financial amortization duration time corresponding to the purchase of a mixer, is found under 2 years. Although the chosen application case is simplified, these results encourage further research.

REFERENCES

- ACI Committee, 2005. Evaluation of Strength Test Results of Concrete (ACI 214R-02). American Concrete Institute, Farmington Hills, MI, p. 6.
- Day, K.W., 1995. Concrete Mix Design, Quality Control and Specification. E&FN Spon. 109e157.
- ERMCO, August 2006. European Ready-mixed Concrete Industry's Statistics. Report from the European Ready-mixed Concrete Organization, 11 pp.
- Heijungs, R., Guinee, J. B., Huppes, G., Lankveijer, R. M., Udo de Haes, H. A. and Wegner Sleeswijk, A. 1992. Environmental life cycle assessment of products. Backgrounds and Guide. Centre of Environmental Science, Leaden. 130 + 100 s
- Hoffman G.K., Uses of Fly Ash from New Mexico Coals. New Mexico Geology, 22, 2, 25-36 (2000).
- Josa, A., Aguado, A., Heino, A., Byars, E., Cardim, A., 2004. Comparative analysis of available life cycle inventories of cement in the EU. Cement and Concrete Research 34, 1313e1320.
- JSCE. 2004. Assessment for Environmental Impact of Concrete (Part 2), Japan Society of Civil Engineers, Concrete Engineering Series 62.
- Kawai, K., Sugiyama, T., Kobayashi, K., & Sano, S. 2005a. A Proposal of Concrete Structure Design Methods Considering Environmental Performance, Journal of Advanced Concrete Technology, 3(1), 41-51.
- Pade, C., Guimaraes, M., 2007. The CO2 uptake of concrete in a 100 year perspective. Cement and Concrete Research 37, 1348e1356.
- Stripple, H., 2001. Life cycle assessment of road. A pilot study for inventory analysis. 2nd revised Edition. Report from the IVL Swedish Environmental Research Institute, 96.