ENVIRONMENTAL IMPACT ASSESSMENT OF CONCRETE INDUSTRY IN IRAN

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ABSTRACT

Constructional industry as the largest consumer of natural materials produces the most portion of the wastes in the country. Concrete being the most commonly used building material in Iran that can have pronounced effect on the production of the waste. Concrete is composed of sand, gravel, crushed rock or other aggregates held together by a hardened paste of hydraulic cement and water. Therefore, evaluation of effects of concrete industry on environment is one of the important cases to be considered. In this paper environmental impact assessment (EIA) of concrete industry is performed, and appropriate recommendations to minimize the effect of environmental impact are given.

Keywords: concrete, environmental impact assessment, sustainable development, IRAN

1. INTRODUCTION

Sustainable development involves meeting present needs without compromising the ability of future generations to meet their needs [1].

The ecological criteria for sustainable development are the preservation of biodiversity and adoption of human activities to the natural resources and tolerance of nature [2]. For this purpose there is increasing concern now that the choice of construction materials must also be governed by ecological considerations.

At the beginning of the 20th Century, the world population was 1.5 billion; by the end of that Century it had risen to 6 billion. Considering that it took 10,000 years after the last ice age for the population to rise to the 1.5 billion mark, the rate of growth from 1.5 to 6 billion people is remarkable [1]. Unfortunately, our choices for technology have turned out to be wasteful, because decisions are based on short term and narrow goals of enterprise rather than a holistic view of the full range of consequences from the use of a technology. Only 6% of the total global production of materials, some 500 billion tons a year, actually ends up in consumer products, whereas much of the virgin materials are being returned to the environment in the form of harmful solids, liquids, and gaseous wastes. The greatest environmental challenge today is that of the human-made climate change due to global warming caused by steadily rising concentration of green-house gases in the earth's atmosphere during the past 100 years [3].

An (EIA) is an assessment of the possible impact (positive or negative) that a
The environmental impact of building products consists of procurement of raw materials, the manufacturing process and also the use of energy resources during transportation – all of which to some extent burden the environment. Environmental burdens of the cement industry consist of limestone quarrying, burning and grinding of clinker. Extraction, excavation, manufacturing and transportation of aggregates and distribution of the final products are elements for EIA of concrete industry [2].

After water, concrete is the second most widely consumed substance on earth. Using concrete minimizes the depletion of our natural resources. Its ingredients come directly from readily available materials: water, aggregate (sand and gravel or crushed stone), and cement. Cement is composed of 75% limestone, the most common mineral on earth. Although extracting any raw material from the earth takes a toll on the environment, extracting the raw materials for concrete has a lower impact than that of other construction materials. Because the ingredients for concrete are so plentiful, supplies are virtually inexhaustible.

The goal of this paper is to identify the environmental impacts of concrete and its products which in-turn can lead to determining options for improving environmental effects.

2. EIA OF CONCRETE INDUSTRY IN IRAN

I.R. Iran is located in the center of the Middle East and bridges the Caspian Sea to the Persian Gulf and the east of Asia to the west of Asia. Because of its strategic location it is one of the important countries in the region. Iran has complex climate ranging from subtropical to sub polar and that it is possible at the same time to witness the climatic conditions of all four seasons in the different parts of its territory. The building industry is one of the most important industries in Iran, concrete being the most widely used material. Therefore the concrete industry is very important from the point of view of EIA.

2.1. Concrete Components

Ordinary, concrete typically contains about 12 percent cement, 8 percent mixing water, and 80 percent aggregate by mass. The 11.5 billion tones-a-year concrete industry is thus the largest user of natural resources in the world. The demand for concrete is expected to grow to approximately 18 billion tons (16 billion tones) a year by 2050 [4]. This means that, in addition to 50 million tones of cement (current annual production of cement in Iran), the concrete industry in Iran is consuming annually 137 million tones of fine and coarse aggregate together with 15 billion liters of mixing water.

2.1.1. Cement

The examination of concrete manufacturing shows that the cement, which usually makes up 10–15% of concrete, is the main environmental polluter. Cement manufacturing covers material and energy flows during the extraction of materials, and the production processing such as raw meal, clinker burning, grinding and transportation of the product. Because of the high temperatures used during cement
production and the decomposition of calcium carbonate, the cement accounts for over 60% of energy used in concrete manufacturing. The amount of cement production and consumption per capita in Iran is shown in figure 1. Estimated world cement production and CO\textsubscript{2} emission in cement manufactures are shown in figure 2 and 3 respectively [2].

![Figure 1. Cement production and consumption per capita in IRAN (1963-2007) [5]](image1)

![Figure 2. World Cement Production](image2)
The most serious problem with cement industry is that it is a major CO₂ emitter causing global warming. With every ton of cement produced, almost a ton of CO₂ is emitted [6]. About 0.5 tons comes from the decomposition of limestone and the balance is generated by power plant supplying electricity to turn the kiln and ball mills to grind the cement plus the fuel burned to fire the kiln. All other sources of CO₂ emission such as operating ready mix trucks adds only a minor. In terms of conventional concrete mixtures (not containing fly ash, slag or silica fume), about 480 kg of CO₂ is emitted per cubic meter of concrete or 20 kg of CO₂ per 100 kg of concrete produced. All of this amounts to about 7% of the total CO₂ generated worldwide [7]. Enhanced efficiency is not likely to change this but the replacement of some of the cement by a supplementary cementing material not associated with CO₂ emissions can substantially reduce these emissions.

- **Nitrous Oxide Emissions**

Nitrous oxide emissions come from burning gasoline, coal or other fossil fuels. Ozone is formed when nitrogen oxides and volatile organic compounds mix in sunlight. The volatile organic compounds come from sources ranging from industrial solvents to volatile resins in trees. Ozone near the ground can cause a number of health problems such as asthma attack, sore throat, coughing and other health difficulties. In addition, nitrous oxide, carbon dioxide and methane are the most important greenhouse gases [8].

The NOₓ emissions from Canadian cement kilns range from 1.5 to 9.5 kg/tones of
clinker produced with a proposed limit of 2.3 kg of No\textsubscript{x} per tone [6]. Using 2.3 kg of No\textsubscript{x} per tone, the world release of No\textsubscript{x} by the 2130 million tones of cement produced in the year 2020 would be 4.85 million tones of No\textsubscript{x}. This is a fifth of the No\textsubscript{x} released in all of continental Asia in a year [9]. Reduction in nitrous oxides is normally achieved by reducing the burning temperature or by injecting ammonia compounds into the high temperature exhaust stream [6]. This seems like a good idea but when these actions are taken to reduce the No\textsubscript{x} in coal fired electric power generating stations, it adversely affects the quality of the fly ash produced. The fly ash then needs to be treated to remove the unburnt coal and ammonia gas before it can be used in concrete mixtures and several plants doing this are in operation.

- **Particulate Air Emissions**

Particulate emissions from the exhaust gases range from 0.3 to 1.0 kg/tone. It is normally very rich in sodium and potassium which have vaporization temperatures of only 883°C and 774°C respectively. In the past, before there was a concerted effort to capture the particulate emission, the sodium and potassium plume from cement plant chimneys settled over the countryside where it helped to combat acid rain. Now it is mainly carried out in the clinker stream where it creates problems with alkali aggregate reaction [10].

2.1.2. Aggregate

The coarse and fine aggregate content in concrete products is approximately 80% and it covers < 3 % of emissions and energy used. The environmental burdens from procurement of aggregate consist of:
- using raw-materials;
- using land; and
- using energy (in extraction, excavation and crushing of stone materials and in transportation) which causes emissions into air.

Besides these, crushing causes dust emission and quarrying causes land and stone waste. The energy used in gravel excavation and crushing is much less than in production of building materials where heating or grinding is employed (i.e., cement production). Energy used in stone crushing depends on the desired size fraction. Table 1 shows an example of energy used for gravel excavation and Table 2 in quarrying and crushing.

<table>
<thead>
<tr>
<th>Table 1: Energy used in gravel excavation [2]</th>
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<tr>
<td><strong>Gravel excavation</strong></td>
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<tr>
<td>Gravel transport (10 km)</td>
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<td>Total</td>
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<th>Table 2: Energy used in gravel production [2]</th>
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<tr>
<td><strong>Quarrying + Crushing</strong></td>
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<tr>
<td>Removal and transportation</td>
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<td>Total</td>
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2.1.3. Water
The water shortage in Iran is a serious problem and this intensified by seasonal
rainfalls. Only 10 percent of the country receives adequate rainfall for agriculture;
most of this area is in western Iran.
Concrete manufacturing uses normal tap water to make up about 0.06 – 0.10 kg/kg
concrete. The total water supply system consumes very little energy for water
purifying and delivery so the overall environmental impact remains small [2].
On average of each ready mix about half cubic meter of concrete remains in the
truck per day. After concrete is discharged there is still about 300 kg of solids
(cement, sand and stone) that it is necessary to washed out, with about 1000 liters
of water. In the past the returned concrete and the solids were dumped in a pit at
the job site or at the plant. Considering that this represents 2 to 4% of the total
concrete produced, it is now considered too valuable to waste and can be recycled
or reclaimed as sand and gravel. To reclaim the sand and gravel a “reclaimer” is
used. It involves adding water to the returned concrete and then agitating it
followed by wet screening to obtain the sand and gravel. Also, the cement-water
slurry from the reclaimer, the wash out water, water to clean the outside of the
truck, plus any stormwater in the past usually was directed into somewhat
inefficient settling basins and then into a local water course [11-12].

2.1.4. Chemical Admixtures
The most common admixtures in concrete are plasticizers and air entrainers. The
plasticizers used include lignosulphonate salts, hydroxyl-carboxylic acid, modified
melamine, naphthalene and polymers. These are synthetic organic compounds
which have a deflocculating and dispersing effect. They act on the forces between
solid particles suspended in water by reducing the surface tension of water.
Plasticizer content in concrete is typically very low 0.002 – 0.1% (by weight of
cement) so their effect on energy use and emissions of concrete products is very
low. Plasticizers are non-volatile compounds which mean that their effect on the
indoor climate is also inconsequential. Air entraining admixtures are invariably
organic substances which help to generate microscopic bubbles of air in the fresh
concrete to improve concrete frost resistance. Air entraining agents are based on
carboxyl acid salts, alkyl sulphonates, and phenolethoxysylates. The most common
air entraining agents are made from pine oil and they are alkali metal salts. Pine oil
consists of fat and resin acid compounds, which are produced from sulphate pulp
processing. Air entraining admixture content in concrete is also typically very low
0.002 – 0.02% (by weight of cement) so their effect on energy use and emissions of
concrete products is very low [2].

2.1.5. Mineral Admixtures
- Fly Ash
Substitution of cement or natural aggregates with industrial by-products can be
done in concrete production. From an environmental point-of-view this result is
saving our natural resources and land. It is possible to substitute concrete aggregate
with wastes from metal productions, mining industry or mineral stone industry by-
products such as ferrochrome slag or blast-furnace slag. In some cases when using by-products the crushing and transportation can consume more energy than in procurement of the natural resources.

Fly ash from power plants can be used as a substitute for cement or filler. Ash which contains desulphurization products rich in sulphate or sulphite is not suited for making concrete. By using fly ash the environmental profile of concrete or concrete products can be affected only by the ash transport burden. Approximately 10–30% of cement content can be substituted by fly ash without much effect on concrete properties [2]. Currently in Iran fly ash is not produced but natural pozzolanic materials and silica fume are available and can be used.

- **Blast-furnace slag**
Cement can also be substituted by ground granulated blast-furnace slag. Blast-furnace slag is a by-product of crude iron production and its economical value is negligible compared to the crude iron. As such blast-furnace slag is not suited for use as concrete binder because to achieve hydraulic properties it needs to be cooled fast, dried and ground to typical cement fineness. Blast-furnace slag processing uses less energy and causes considerably less emissions than cement manufacturing, so already a small amount of cement substitution with blast-furnace slag lowered environmental burdens. Blast-furnace cement has 10% blast-furnace slag addition but it could be increased to approximately 70% of the total binder content. Compared to concrete composed of 100% cement, the appropriate use of blast-furnace slag in concrete products as a cement substitute decreases environmental effects [2]. The bad quality of blast-furnace slag in Iran limited its content in concrete to 10-15%.

### 2.2. Durability of Concrete for Eia

One of the most important considerations in the concrete industry is the durability of concrete. When a concrete structure has inadequate durability it causes solid waste generation sooner than it is expected. From an environmental point of view it is essential that every concrete structure should continue to perform its intended functions, which are maintaining its required strength and serviceability during the specified or traditionally expected service life. Improving concrete durability can cause a decrease in solid waste generation in building industry. Therefore quality control of concrete in the Persian Gulf environment has a long record of stigma attached for its harsh climate, desert features and saline waters that do not render the longevity of concrete is very important [13]. Use of supplementary cementitious materials such as silica fume and blast furnace slag with Portland cement has increased durability of concrete in the Persian Gulf region and therefore decreased solid waste form short-lived concrete.

### 2.3. Recycle of Industrial and Building Wastes for Use in Concrete

Recycled aggregate concrete has become the focus in the past decades due to its great environmental effect. In the USA, about 30 million tons of concrete has to be discarded each year. This number increased from 55 million tons in 1980 to 162
million tons in 2005, approximately tripled in less than 30 years. China faces a more serious problem to cope with discarded concrete with the increasingly rapid urbanization process. For example, Shanghai City alone, wastes concrete 20 million tons annually. Other reasons may also lead to waste concrete. An 8.0 magnitude earthquake in Sichuan province, China on 12th May, 2008 caused collapse of at least four millions houses, which produced tremendous discarded concrete. Similar problems are presented in Iran. Recycling of concrete is, therefore, becoming increasingly important to ensure sustainable development both in world [14]. Waste management and disposal is a major environmental concern in many countries and increasingly becoming a significant environmental, health, and aesthetic problem that is not easily solved [15]. Therefore due to the increasingly serious environmental problems presented by hazardous industrial wastes, the feasibility of burying these materials as aggregate in concrete would be of great interests.

3. CONCLUSION & DISCUSSION

- Constructional industry as the largest consumer of natural materials produces the most portion of the wastes in the country. The concrete industry has potential for environmental pollution.
- With the exception of CO$_2$ and NO$_x$ emissions, by using our current technology all the perceived environmental problems with concrete can be effectively resolved. The concrete industry needs to focus on these two greenhouse gases.
- In the concrete industry the easiest and most effective way to reduce greenhouse gases is to increase the use of such silica rich by-products as slag and silica fume and natural pozzolanes, thereby reducing the amount of cement used per cubic meter of concrete.
- Concrete industry generates about 7% of the total CO$_2$ generated globally and if we assume that only 18.5% of the cement can be replaced with slag or fly ash, then the CO$_2$ reduction would be 300 million tons per year worldwide.
- Over the past decade the average annual increase in CO$_2$ emissions has been 1.3 percent or nearly 300 million tons a year. Therefore our industry could greatly help in easily reducing global warming and at the same time enhance the properties of the concrete.
- Improvement in the durability of concrete in corrosive environments such as the Persian Gulf that has a long record of stigma attached for its harsh climate, desert features and saline waters, can help to reduce solid waste generated from short-lived concrete in these regions.
- The recycling of industrial and building wastes for use in concrete can have significant effect for the environment.

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