

Center for By-Products Utilization

ENVIRONMENTAL-FRIENDLY CONCRETE WITH INDUSTRIAL AND POST-CONSUMER BY- PRODUCTS

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Environmental-Friendly Concrete with Industrial and Post-Consumer By-Products

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ABSTRACT

Concrete is one of the most widely used construction materials in the world. However, the production of portland cement, an essential constituent of concrete, leads to the release of significant amount of CO₂, a greenhouse gas; one ton of portland cement clinker production creates one ton of CO₂ and greenhouse gases (GHGs). Environmental issues will play a leading role in the sustainable development of the cement and concrete industry in this century. For example, if we run out of limestone, as it is predicted to happen in some places, then we cannot produce portland cement and, therefore, we cannot produce concrete and all the employment associated with the concrete industry goes out-of-business. Ground limestone is sometimes interground with clinker to produce cement, reducing the needs for clinker making and calcinations. This reduces energy use in the kiln and CO₂ emissions from calcinations. A sustainable concrete structure is one that is constructed so that the total environmental impact during the entire life cycle, including during its use, is minimum. Concrete is a sustainable material because it has a very low inherent energy requirement, is produced to order with very

little waste, is made from some of the most plentiful resources on earth produces on as-needed basis, has very high thermal mass, can be made with recycled materials, and is completely recyclable. Sustainable design and construction of structures have a small impact on the environment, use “green” materials embody low energy costs, have high durability and low maintenance, contain a large proportion of recycled or recyclable materials, and use less energy and resources. High performance cements and concrete can reduce the amount of cementitious materials and total volume of concrete required. Concrete must keep evolving to satisfy the increasing demands of all its users. Reuse of post-consumer wastes and industrial by-products in concrete is necessary to produce even “greener” concrete. Use of coal ash, rice-husk ash, wood ash, GGBFS, silica fume, and other similar pozzolanic materials can reduce the use of manufactured portland cement clinker, and at the same time produce concrete that is more durable. “Greener” concrete also improves air quality, minimizes solid wastes, and leads to sustainable cement and concrete industry.

Keywords: by-products, energy, recycling, environment, portland cement, pozzolan, sustainable concrete.

INTRODUCTION

Concrete is one of the most widely used construction materials in the world. However, the production of portland cement, an essential constituent of concrete, leads to the release of significant amount of CO₂, a greenhouse gas. One ton of Portland cement clinker production creates one ton of CO₂ and other greenhouse gases (GHGs). Environmental issues will play a leading role in the sustainable development of the cement and concrete industry in this century.

According to the World Commission on Environment and Development: sustainability means “Meeting the needs of the present without compromising the ability of the future generations to meet their own needs.” Sustainability is an idea for concern for the well being of our planet with continued growth and human development [1].

For example, if we run out of limestone, as it is predicted to happen in some places, then we cannot produce portland cement and, therefore, we cannot produce concrete; and, all the employers associated with the concrete industry goes out-of-business, along with their employees.

Over 5 billion ton of non-hazardous by-product materials are produced each year in USA (2002). At an average disposal cost of \$30 per ton, it would cost \$150 billion to throw it all away. These by-products are from agricultural sources, domestic sources, industrial sources, and materials processing sources.

Environmental Issues

The production of portland cement releases CO₂ other greenhouse gases (GHGs) into the atmosphere. Total CO₂ emissions worldwide were 21 billion tons in 2002, Table 1.

Table 1. CO₂ Emissions by Industrialized Countries in 2002 [2]

Country	Percent, CO ₂
U.S.A.	25
E.U.	20
Russia	17
Japan	8
China	>15
India	>10

Environmental issues associated with the CO₂ emissions from the production of portland cement, energy demand (six-million BTU of energy needed per ton of cement production), resource conservation consideration, and economic impact due to the high cost of portland cement manufacturing plants demand that supplementary cementing materials in general and fly ash in particular be used in increasing quantities to replace portland cement in concrete [2, 3].

Fly ash is a by-product of the combustion of pulverized coal in thermal power plants. The dust-collection system removes the fly ash, as a fine particulate residue from the combustion gases before they are discharged in the atmosphere.

For each ton of portland cement clinker, 3 to 20 lbs. of NO_x are released into the atmosphere. In 2000, the worldwide cement clinker production was approximately 1.6 billion tons [2].

Yomiuri Shimbun reported from Kobe, Japan that: “The Hyogo prefecture government on (Oct. 1, 2004) banned automobiles with emissions of nitrogen oxide (NO_x) and particulate matter that exceed levels set in a law concerning these emissions from traveling in certain parts of the prefecture.”

Thermal mass of concrete contributes to operating energy efficiency and reduced cooling costs, under certain climatic conditions. Longer lasting concrete structures reduce energy needs for maintenance and reconstruction. Made to order concrete means less construction waste. Concrete is a locally available material; therefore, transportation cost to the project site is reduced. Light colored concrete walls reduce interior lighting requirements. Permeable concrete pavement and interlocking concrete pavers can be used to reduce runoff and allow water to return to the water table. Therefore, concrete is,

in many ways, environmentally friendly material. As good engineers, we must use more of it [2].

In view of the energy and greenhouse gas (GHG) emission concerns in the manufacturing of portland cement, it is imperative that either new environmentally friendly cement-manufacturing technologies be developed or substitute materials be found to replace a major part of the portland cement for use in the concrete industry [2].

Coal Combustion Products (CCPS)

It is important to develop recycling technology for high-volume applications of coal combustion products (CCPs) generated by using both conventional and clean-coal technologies. Many different types of CCPs are produced; for example, fly ash (Class F since 1930s, and Class C since early 1980s), bottom ash, cyclone-boiler slag, and clean-coal ash (since late 1980s, ash derived from SO_x/NO_x control technologies, including FBC and AFBC or PFBC boilers, as well as dry- or wet-FGD materials from SO_x/NO_x control technologies). In general some of these CCPs can be used as a supplementary cementitious materials and use of portland cement, therefore, can be reduced.

The production of CCPs in USA is about 100 million tons per year (from about 55% of total electricity & steam production). Cyclone-boiler slag is 100% recycled. Overall recycling rate of all CCPs is about 33%. High-sulfur coal ashes, such as Class F fly ash and especially clean-coal ashes, are underutilized.

For 2002, in USA, Fluidized Gas Desulphurization (FGD) Gypsum: 11.4 MT (million tons) produced, 7.8 MT used (70%); FGD wet-Scrubbers: 16.9 MT, 0.5 MT (3%); FGD Dry-Scrubbers: 0.9 MT, 0.4 MT (45%); and, A/FBC Ash: 1.2 MT, 0.9 MT (75%). Overall, 30.4 MT produced, 9.6 MT used (32%).

Today use of other pozzolans, such as rice-husk ash, wood ash, GGBFS, silica fume, and other similar pozzolanic materials such as volcanic ash, natural pozzolans, diatomite (diatomaceous earth), calcined clay/shale, metakaolin, very fine clean-coal ash (micro-ash), limestone powder, and fine glass can reduce the use of manufactured portland cement, and make concrete more durable, as well as reduce GHG emissions. Chemical composition of ASTM Type I portland cement and selected pozzolans is given in Table 2.

Table 2. Chemical Composition of CCPs

Oxides %	portland Cement	St. Helen's Ash	VPP Class F Ash	Colombia Unit #1 Fly Ash	P-4 Class C Ash
SiO ₂	20.1	62.2	48.2	44.8	32.9
Al ₂ O ₃	4.4	17.6	26.3	22.8	19.4
CaO	57.5	5.7	2.7	17.0	28.9
MgO	1.6	2.2	1.1	5.1	4.8
Fe ₂ O ₃	2.4	5.6	10.6	4.2	5.4
TiO ₂	0.3	0.8	1.2	1.0	1.6
K ₂ O	0.7	1.2	2.3	0.4	0.3
Na ₂ O	0.2	4.6	1.1	0.3	2.0
Moisture	0.2	0.4	0.4	0.1	0.8
LOI	1.1	0.6	7.9	0.3	0.7

SUSTAINABILITY

Entire geographical regions are running out of limestone resource to produce cement. Major metropolitan areas are running out of sources of aggregates for making concrete. Sustainability requires that engineers consider a building's "life-cycle" cost extended over the useful lifetime. This includes the building construction, maintenance, demolition, and recycling [5, 6].

A sustainable concrete structure is one that is constructed so that the total societal impact during its entire life cycle, including during its use, is minimum. Designing for sustainability means accounting in the design the full short-term and long-term consequences of the societal impact. Therefore, durability is the key issue [5]. New generation of admixtures/additives are needed to improve durability.

To build in a sustainable manner and conduct scheduled & appropriate building maintenance are the keys that represent the “new construction ideology” of this millennium. In particular, to build in a sustainable manner means to focus attention on physical, environmental and technological resources, problems related to human health, energy conservation of new and existing buildings, and control of construction technologies and methods [6].

Traffic tunnel being built in Akita, Japan (2001 – 2007) is expected to cost about 625 million USD (about 70 billion Yens). If it is not constructed as a durable infrastructure, with a minimum life-cycle cost, then say 45 years from now it would cost 700 billion Yen. 2004 cost is 5 USD (550 Yens) per person in Japan (Population: 127.6 million, in May 2004; down 50,000 from a year ago, The Japan Times, Oct. 21, 2004). If the population of Japan, as expected in 2050 is 100 million, then it would cost 7,000 Yen per person to re-build this tunnel. Would it be re-built?

CONCRETE

Concrete is environmentally very friendly material. As good engineers, we must use more of it in construction [2]. Concrete has been used for over 2,000 years. Concrete is best known for its long-lasting and dependable nature. However, the additional ways that concrete contributes to social progress, economic growth, and environmental

protection are often overlooked. Concrete structures are superior in energy performance. They provide flexibility in design as well as affordability, and are environmentally more responsible than steel or aluminum structures [4].

“The concrete industry will be called upon to serve the two pressing needs of human society; namely, protection of the environment and meeting the infrastructural requirement for increasing industrialization and urbanization of the world. Also due to large size, the concrete industry is unquestionably the ideal medium for the economic and safe use of millions of tons of industrial by products such as fly ash and slag due to their highly pozzolanic and cementitious properties. It is obvious that large-scale cement replacement (60-70 %) in concrete with these industrial by-products will be advantageous from the standpoint of cost economy, energy efficiency, durability, and overall ecological profile of concrete. Therefore, in the future, the use of by-product supplementary cementing materials ought to be made mandatory” [2].

SUSTAINABLE CONCRETE SOLUTIONS

Concrete is a strong, durable, low environmental impact, building material. It is the cornerstone for building construction and infrastructure that can put future generations on the road towards a sustainable future [4]. Benefits of concrete construction are many, for example [4]: concrete buildings – reduce maintenance and energy use; concrete highways – reduce fuel consumed by heavily loaded trucks; insulating concrete homes – reduce energy usage by 40% or more; cement-based solidification/stabilization and in-situ treatment of waste for brownfield redevelopment; and, agriculture waste containment – reduces odor and prevents groundwater contamination. The concrete industry must show leadership and resolve, and make contribution to the sustainable development of the

industry in the 21 century by adopting new technologies to reduce emission of the greenhouse gases, and thus contribute towards meeting the goals and objectives set at the 1997 Kyoto Protocol. The manufacturing of portland cement is one such industry [2].

PORTLAND CEMENT

Portland cement is not environmentally very friendly material. As good engineers, we must reduce its use in concrete [2]; and, we must use more blended cements, especially with chemical admixtures.

Clinker production is the most energy-intensive stage in cement production, accounting for over 90% of total energy use, and virtually all of the fuel use. Processing of raw materials in large kilns produces portland cement clinker. These kiln systems evaporate the inherent water in the raw materials blended to manufacture the clinker, calcine the carbonate constituents (calcinations), and form cement minerals (clinkerization) [7].

Blended Cements

The production of blended cements involves the intergrinding of clinker with one or more additives; e.g., fly ash, granulated blast furnace slag, silica fume, volcanic ash, in various proportions. The use of blended cements is a particularly attractive efficiency option since the intergrinding of clinker with other additives not only allows for a reduction in the energy used (and reduced GHG emissions) in clinker production, but also directly corresponds to a reduction in carbon dioxide emissions in calcinations as well. Blended cement has been used for many decades around the world [7].

Concrete and the Use of Blended Cements

Although it is most common to make use of supplementary cementing materials (SCM) in the replacement of cement in the concrete mixture, blended cement is produced at the

grinding stage of cement production where fly ash, blast furnace slag or silica fume are added to the cement itself. The advantages include expanded production capacity, reduced CO₂ emissions, reduced fuel consumption and close monitoring of the quality of SCMs [4].

“Kyoto Protocol (UN Pact of 1997, requires to reduce GHGs, including CO₂). It has been ratified by 124 countries, including EU and Japan.” Russia is now in a process to ratify it. USA has not ratified it. “The Russian Government approval (would) allow it to come into force worldwide.” By 2012, emissions must be cut below 1990 levels (in Japan by $6.0 + 7.6 = 13.6\%$ by 2012) [9].

In Japan “(Per) household...5,000 yen green tax” per year is planned for 2005 (starting April). This includes “3,600 yen in tax per ton of carbon.” “The revenue would be used to implement policies to achieve the requirements of Kyoto Protocol.” A survey released (on Oct. 21, 2004) showed that 61% of those polled are in favor of the environmental tax.” [10].

Rate of CO₂ Emission and Global Warming as shown in Fig. 2 [16]. In last 2 yrs. CO₂ has increased at a higher rate than expected [10].

Foundry By-Products

Foundry by-products include foundry sand, core butts, abrasives, and cupola slag. Cores are used in making desired cavity/shapes in a sand mold in which molten metal is cast/poured. Cores are primarily composed of silica sand with small percentages of either organic or inorganic binders.

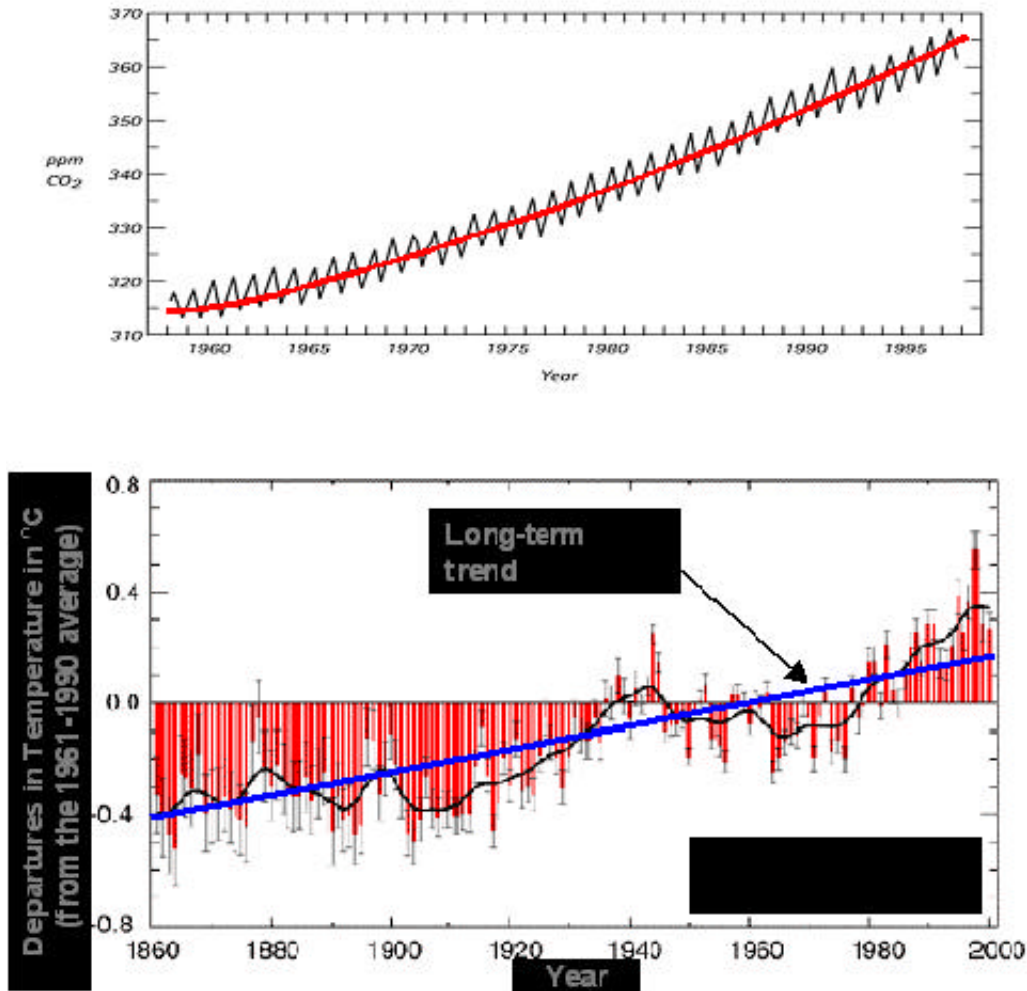


Figure 2. CO₂ Emission and Global Warming [16]

Green sand for making molds is composed of four major materials: sand, clay (4 to 10%), additives, and water. Sand usually constitutes 50 to 95% of the total materials. . Foundries in USA generate approximately 15 million tonnes of by-products annually. Wisconsin alone produces nearly 1.1 million tonnes (1.25 million tons) of foundry by-products, including foundry sand and slag. Most of these by-products are landfilled. Landfilling is not a desirable option because it not only causes huge financial burden to foundries, but also makes them liable for future environmental costs, problems, and

restrictions associated with landfilling. Furthermore, the cost of land filling is escalating due to shrinking landfill space and stricter environmental regulations. One of the innovative solutions appears to be high-volume uses of foundry by-products in construction materials [11]. Table 3 provides physical properties of foundry sand.

Table 3. Physical Properties of Used Foundry Sand

Property	Value	Test Method
Specific Gravity	2.39	ASTM D 854
Unit Weight, kg/m ³	2590	ASTM C 48
SSD Absorption, %	0.45	ASTM C 128
Coefficient of	10 ⁻³	ASTM D 2434

Applications of Used Foundry Sand [11]

Foundry sand can be used as a replacement of regular sand up to 45% by weight, to meet various requirements of structural-grade concrete (1991). Use of foundry sand in concrete may result in some loss of concrete strength due to increased water demand. However, proper mixture proportioning can compensate this.

Concrete of compressive strength 42 MPa has been produced with the inclusion of foundry sand up to 45% replacement of regular sand. Flowable slurry (CLSM), incorporating used foundry sand as a replacement of fly ash up to 85% has also been produced (1996).

Up to 15% used foundry sand can be used as replacement of fine aggregate in Hot Mix Asphalt (HMA). Bricks, blocks, and paving stones made with up to 35% used foundry sand passed ASTM requirements for compressive strength, absorption, and bulk density.

Environmental impact of the use of Controlled Low Strength Materials (CLSM) incorporating industrial by-products (coal fly ash, and used foundry sand) has been

reported [11]. The results demonstrated that excavatable flowable slurry incorporating fly ash and foundry sand up to 85% could be produced. In general, inclusion of both clean and used foundry sand caused reduction in the concentration of certain contaminants. The use of foundry sand in CLSM slurry, therefore, provided a favorable environmental performance. All fly ash slurry materials made with and without foundry sand were environmentally friendly materials [11].

Applications of Foundry Slag

Foundry (cupola) slag is appropriate for use as a coarse semi-lightweight aggregate in cement-based materials. It has been used as replacement of aggregate in manufacturing of structural-grade concrete.

Post-Consumer Glass

Approximately 10 million tonnes of post-consumer glass is produced each year in USA. About 3.4 million tonnes is used primarily as cullet for glass manufacturing. There are three types of glass: borosilicate, soda-lime, and lead glass. The majority of glass manufactured in USA is soda-lime variety. Glass primarily consists of silica or silica sand.

Applications of Post-Consumer Glass [17]

Crushed glass is highly reactive with cement (alkali-silica reaction). But Class F fly ash was used as a replacement of cement by mass of 45% or more, which helped in controlling alkali-silica reaction (1999). Mixed colored glass can be utilized in flowable self-compacting concrete (1998). Addition of mixed colored glass increased

impermeability of concrete as the age increased. It can be used as partial replacement of sand in other cement-based materials.

Wood ash [18]

Wood ash is the residue generated due to combustion of bark, wood, and scraps from manufacturing operations (pulp mills, saw mills, and wood products manufacturing plants), and from CDW (construction and demolition wastes). Wood ash is composed of both inorganic and organic compounds. Yield of wood ash decreases with increase in combustion temperature.

Applications of Wood Ash

Wood fly ash has substantial potential for use as a pozzolanic mineral admixture and as an activator in cement-based materials. Wood ash has been used in the making of structural-grade concrete, bricks/blocks/paving stones, flowable slurry, and blended cements (1997-2002).

Air-entrained concrete can be achieved by using wood fly ash up to 35%. Structural-grade concrete can be made using wood fly ash and its blends with Class C fly ash to achieve a compressive strength of 50 MPa or higher. Physical and chemical properties of wood ash are given in Table 4 and 5, respectively.

Table 4. Physical Properties of Wood ash

Property	Fly Ash	Bottom Ash
Specific Gravity	2.32 – 2.76	1.55 – 1.75
Unit Weight, kg/m ³	365-920	663-977
Cement activity Index	49 – 90	--

Table 5. Chemical Composition of wood Ash

Constituent	Fly Ash	Bottom Ash	ASTM C 618 Requirements for coal fly ash		
			Class N	Class C	Class F
SiO ₂ , %	4.0 – 59.3	32.2 – 50.7	-	-	-
Al ₂ O ₃ , %	5.0 – 17.0	15.5 – 20.3	-	-	-
Fe ₂ O ₃ , %	1.0 – 16.7	4.7 – 20.8	-	-	-
SiO ₂ +Al ₂ O ₃ +	10 – 72.2	56.9 – 93.4	70 Min	50 Min	70 Min
CaO, %	2.2 – 36.7	4.2 – 22.2	-	-	-
MgO, %	0.7 – 6.5	0.9 – 4.8	-	-	-
TiO ₂ , %	0.0 – 1.2	0.7 – 1.5	-	-	-
K ₂ O, %	0.4 – 13.7	0.5 – 2.2	-	-	-
Na ₂ O	0.5 – 14.3	0.5 – 1.3	--	--	--
SO ₃	0.1 – 15.3	0.1 – 0.7	5 Max	5 Max	5 Max
LOI	0.1 – 15.3	1.4 – 33.2	10 Max	6 Max	6 Max
Moisture Content	0.1 – 21.5	0.2 – 0.9	3 Max	3 Max	3 Max
Available Alkali	0.4 – 20.4	--	1.5 Max	1.5 Max	1.5 Max

Pulp and Paper Mill Residual Solids [19]

More than six million dry tonnes of residual solids from primary clarifiers are generated each year in USA. Pulp and paper mill sludge is composed of cellulose fibers, clay, ash-bearing compounds, chemicals, and moisture. 50% of residuals are landfilled, 25% is incinerated, and the final 25% is utilized in some way. Fig. 3 shows wastewater treatment process at a typical pulp and paper mill.

Primary Residual

Solids are removed at the primary clarifier by sedimentation or dissolved air flotation. Such solid residuals consist mainly of cellulose fibers, moisture, and papermaking fillers

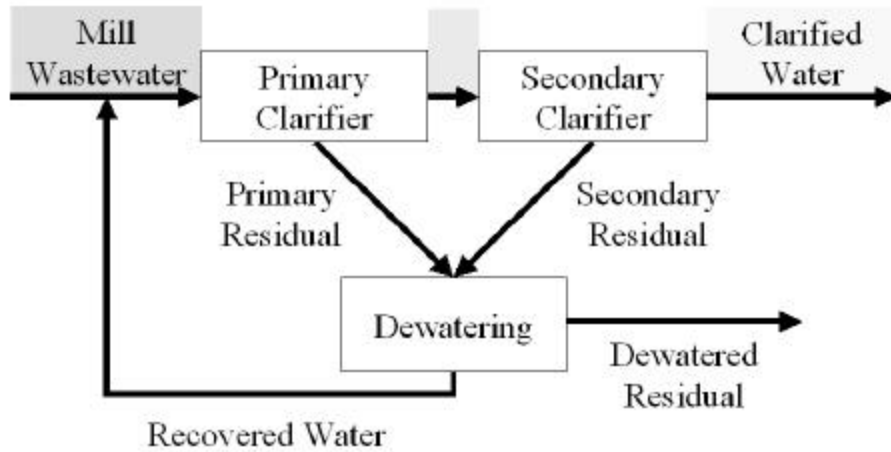
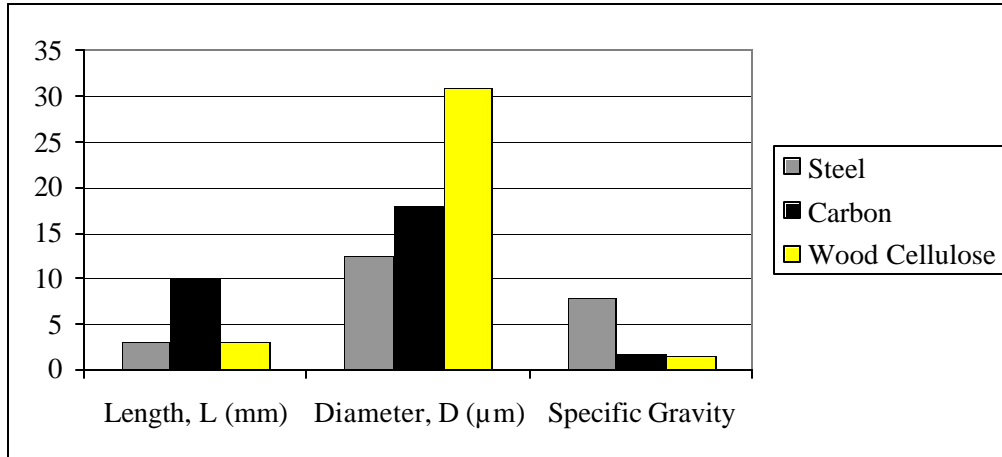


Figure 3. Pulp and Paper Mill Wastewater Treatment Process

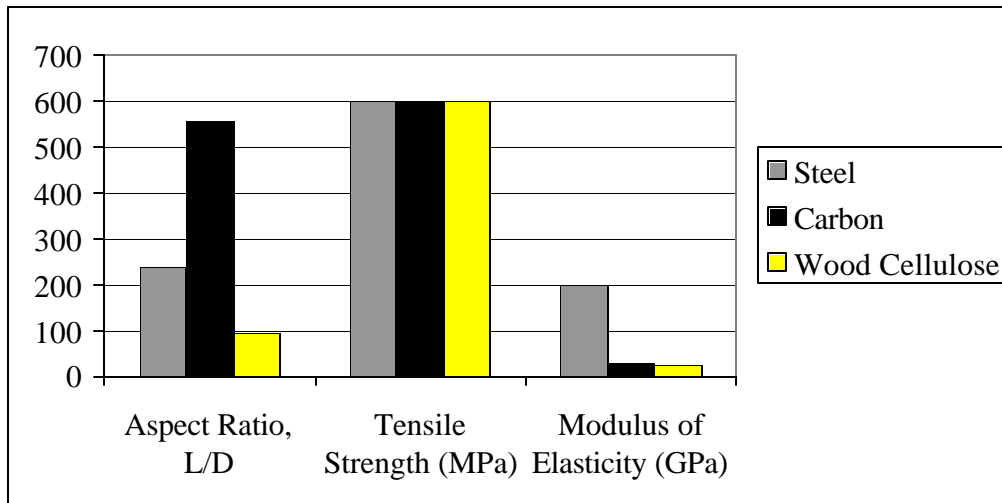
(kaolinitic clay, calcium carbonate, etc.). Table 6 provides typical chemical composition of primary residuals. Figure 4 a provides properties of steel, carbon, and cellulose microfibers.

Table 6. Chemical Composition of Primary Residuals

Constituents	Value
CaO	0.55 - 31.46
SiO ₂	9.29 - 21.78
Al ₂ O ₃	3.37 - 19.13
MgO	0.2 - 1.7
TiO ₂	0.04 - 4.62
LOI	55.4 - 83.4



(a) Physical properties



(b) Mechanical properties

Figure 4. Properties of Microfibers

Applications of Pulp and Paper Mill Residual Solids [20]

Residual solids are used in mine reclamation, farmland soil improvement, bulking agent for composting, raw material for composting, filler in recycled paperboard, oil absorbent granules, odor absorbent granules, additives in cement manufacture (or for a new source

of pozzolan from de-ink solids), and to produce structural-grade concrete. Residual solids reduced somewhat the chloride-ion penetrability of concrete and enhanced the salt-scaling and freezing and thawing resistance of concrete.

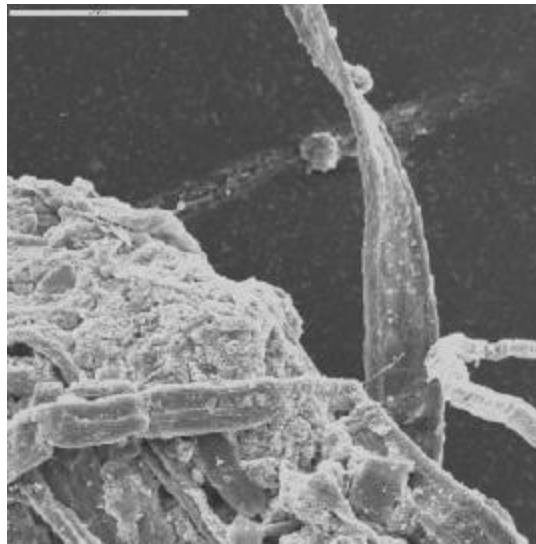


Figure 5. Pulp & Paper Mill Sludge, 500X Magnification

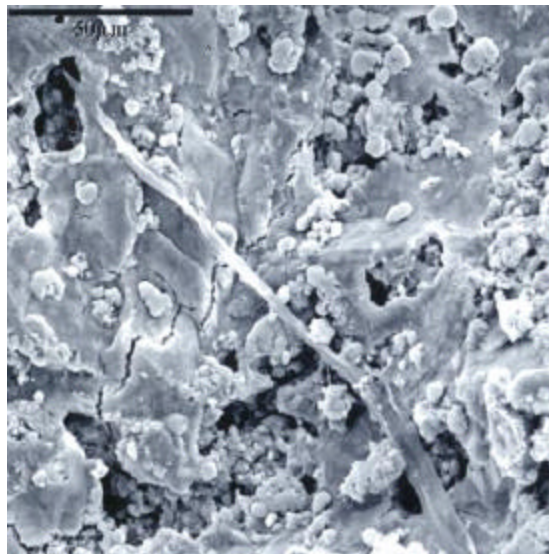


Figure 6. Sludge Fiber Reinforcing a Micro-Crack in Concrete

Resource Conservation

The production of one ton of portland cement requires 1.6 tons of raw materials. These materials are primarily good quality limestone and clay. Therefore, for 1.6 billion tons of cement annually we need about 2.5 billion tons of raw materials.

CO₂ and other GHG emissions can be reduced by the use of other cementitious materials. [CM]. Replacing 15% of cement worldwide by other CM will reduce CO₂ emissions by 250 million tons. Replacing 50% of cement worldwide by other CM will reduce CO₂ emissions by 800 million tons. This is equal to removing 1/4 of all automobiles in the world [2].

THE HANNOVER PRINCIPLES ON DESIGN FOR SUSTAINABILITY [1]

In 1991, City of Hannover, Germany commissioned William McDonough and Michael Braungart to develop a set of sustainability principles to guide development associated with the EXPO 2000 World's Fair in Hannover. The resulting document, "The Hannover Principles - Design for Sustainability" includes guidelines pertaining to water, which are included below. While these guidelines were developed for the World's Fair, they remain useful on a much broader scale.

The Principles are to be considered by designers, planners, government officials, and all involved in setting priorities for the built environment. They will help form the foundations of a new design philosophy underlying the future of proposed systems and construction for the City, its region, its global neighbors and partners in the world exposition. World history offers many examples of societies with environmentally sustainable structures and communities that have endured for thousands of years.

However, we have also pursued other paths that have led to ecologically unsustainable practices. For the development and improvement of humankind, it is imperative to renew a commitment to living as part of the earth by understanding development and growth as processes which can be sustained, not exploited to impractical limits. It is hoped that the Hannover Principles will inspire an approach to design that may meet the needs and aspirations of the present without compromising the ability of the planet to sustain an equally supportive future,

Hannover Principles by William McDonough [1]: Insist on rights of humanity and nature to co-exist; recognize interdependence; respect relationships between spirit and matter; accept responsibility for consequences of design; create safe objects of long-term value; eliminate the concept of waste; rely on natural energy flows; understand the limitations of design; and, seek constant improvement by the sharing of knowledge.

The Hannover Principles should be seen as a living document committed to transformation and growth in the understanding of our interdependence with nature, in order that they may adapt as our knowledge of the world evolves.

For sustainability consider your actions on: materials (use indigenous materials); land use (protect and create rich soil); urban context (preserve open spaces); water (use rainwater and gray-water); wastes (recycle), air (create clean air); energy (use solar & wind energy; recycle waste energy); and, your responsibility to nature (create silence) and the future generations (eliminate maintenance).

OBSERVATIONS

Post-consumer wastes and industrial by-products can be and must be used in concrete to make “greener” concrete. Glass, plastics, tires, and other wood fibers can be used.

Recycling of industrial by-products is well established. Use of coal fly ash in concrete started in the 1930s, and volcanic ash has been recycled for several millennia in mortar and concrete (in Egypt, Italy, Mexico, India, and other places).

Recycling minimizes solid waste disposal, improves air quality, minimizes solid wastes, and leads to sustainable cement and concrete industry.

Use less portland cement. Use less water. Use applications specific, high-quality, durable aggregates. Use chemical admixtures. Trade Emissions (refers to air emissions economic mechanism to reduce global greenhouse gases). Fundamental laws of nature say that we cannot create or destroy matter; we can only affect how it is organized, transformed, and used. Obey the rules of nature: use only what you need and never use a resource faster than nature can replenish it.

“We (over) extract from earth what the planet can replace by an estimated 20%, meaning it takes 14.4 months to replenish what we use in 12. Sustainable developments work to reduce that” [13].

CONCLUSIONS

Generally, large volumes of by-product materials are disposed in landfills. Because of stricter environmental regulations, disposal cost is escalating. Recycling not only helps in reducing disposal costs, but also helps to conserve natural resources, providing technical and economic benefits. This is sustainability. Eliminate waste and take life

cycle responsibility/ownership. Think Ecology, Energy, Equity, and Economy. Acknowledge and balance these Es [14].

Foundry sand can be used as a replacement of regular sand in concrete, flowable slurry, cast-concrete products, and other cement-based materials. Foundry slag can be used as semi-light weight coarse aggregate in concrete.

Glass can be used as a partial replacement of fine aggregate in concrete. Wood ash can be used to make structural-grade concrete, blended cements, and other cement-based materials. Structural-grade concrete can be made with pulp and paper mill residual solids.

Sustainable design must use an alternative approach to traditional design that incorporates these changes in the designer's mind-set. The new design approach must recognize the impacts of every design choice on the natural and cultural resources of the local, regional, and global environments [1]. "Save Our Climate" symbol (Fig. 5) can be widely and freely used and is designed "to act as a common and recognizable thread in all communications concerning climate change [15].



Figure 5. COP 9 saw the launch of a new International Climate Symbol developed jointly by WWF, UNEP, Greenpeace and the Dutch Ministry of the Environment [15].

Wangari Maathai, 2004 Nobel Peace Laureate, said “When we destroy our resources, when our resources become scarce, we fight over them. And many wars in the world are actually fought over natural resources,” (in October 2004). She is known as "the Tree Woman of Kenya” because she has planted over 30 million trees since 1977.

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