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The Cement Industry as a Trailblazer in Recycling

Thermal Recycling of Plastic Waste as a Partial Alternative to Natural Fuels

The cement industry has been using waste materials as fuel and secondary materials for some time. Taiheiyo Cement Corporation, in particular, makes it a company-wide policy to use coal ash, sewage sludge, incineration ash, and blast-furnace slag for some raw materials (alternative raw materials = material recycling) and plastic waste as well as used tires, oil waste, and wood waste as a partial alternative to natural fuels (alternative fuels = thermal recycling).

In this report, we profile Taiheiyo Cement's Kumagaya Plant, which, despite an inland location that makes the hauling in of raw materials and the shipping of products difficult, has turned a disadvantage into an advantage through the use of plastic waste and other waste materials for thermal recycling.

●Launch of the ash-to-raw-material business in the cement industry

Taiheiyo Cement Corporation is the leading cement manufacturer in Japan born from the merger (October 1998) of three companies: Chichibu Cement Co., Ltd., Onoda Cement Co., Ltd., and Nihon Cement Co. Ltd. With a 36.3% share of the market (2005 sales figures), Taiheiyo Cement has a significant lead over the No. 2 cement maker.

The Kumagaya Plant, which started out as the Chichibu Cement Kumagaya Plant in 1962, is known for introducing the world's most advanced rotary kiln in 1973.

In 1980, in the aftermath of the second oil shock, the high cost of heavy oil necessitated a changeover to coal, and two years later, the introduction of thermal power generation facilities that collect generated heat on a large scale increased system efficiency all the more.

At the same time, the use of waste materials at the Kumagaya Plant has been progressing since the 1980s, and an experimental plant using ash from the incineration of municipal trash as a raw material for cement began operation in 1998 and a commercial plant of this type began operation in July 2001.

●Turning waste material into a resource triggers a paradigm shift

Located inland, the Kumagaya Plant must rely on freight cars and trucks having poor transport ability relative to ships and must deal with high transport costs as a result.

Limestone, the main raw material of cement, is transported over a distance of about 40 km from mines in the outskirts of Chichibu City and Gunma prefecture using conveyor belts and freight cars. Coal, on the other hand, is imported from China, Russia, Australia, and other countries through Kawasaki Port and transported to the plant by freight cars. The cost of transporting raw materials has consequently been a handicap for the company. On the other hand, the Kumagaya Plant is located within a metropolitan area in which domestic and industrial waste is abundant, and with this in mind, research began in the 1980s on the recycling of waste material making use of cement manufacturing technology. The results of this research became a trigger for a "paradigm shift" that turns the above geographical handicap into an advantage.

●Turning plastic waste, used tired, incineration ash, and blast-furnace stage into raw materials and fuel

The amount of waste discharged from industry in Japan is about 4-hundred-million tons annually. General waste from households is about 50-million tons, with most of that being disposed of in landfills.

This makes for a total of 450-million tons of waste, with about 7% or 30-million tons of that slated for use by the cement industry as a recycled resource. The industry has achieved its target of 400 kg of waste material per 1 ton of cement.

Efforts to turn incineration ash and dust from municipal trash into a cement resource have also been made at the Kumagaya Plant. In 1998, the Kumagaya Plant joined forces with Kumagaya City and Saitama prefecture (local entities that were having difficulties in processing incineration ash) to carry out three-party joint research with the aim of using ash generated in incineration plants and dust collected by dust collectors as a replacement for some cement raw materials. A commercial plant making use of this material was completed in July 2001, and it processes about 63,000 tons of ash material annually (about 1/4 of the annual discharge of Saitama prefecture).

Plastic waste is mainly of the flexible type such as sheets and films discharged from companies, but it also includes other types discharged from households.

Plastic waste delivered in bale-like packaging is cut into chips about 10 mm in size by a grinder and fed as

View of Kumagaya Plant

secondary fuel into a suspension preheater and rotary kiln using high-pressure air (thermal recycling of plastic waste). This plastic waste has a calorific value on par with that of coal, which explains why it is becoming an indispensible recycled resource in the cement industry where high combustion temperatures are required. For the 2006 fiscal year, 365,000 tons of plastic waste were used throughout the entire cement industry with 87,000 tons of that used by Taiheiyo Cement. Studies are planned on expanding the plastic-waste pickup area as far as possible.

Used tires, discarded pachinko machines(like virtical pinball machines), oil waste, and wood waste are also used for thermal recycling here. The reasons why waste materials such as these can be utilized in cement plants are as follows:

- The main components of cement are calcium oxide (burnt lime), silica dioxide, aluminum oxide, and ferric oxide, and waste materials that include these components can be used for some of the cement raw materials.
- In the burning process within the rotary kiln, combustible waste materials can be used in place of some fuels.
- The burnt residue of combustible waste materials can be incorporated as cement raw material resulting in no discharge of secondary waste.
- Because of the high burning temperature of 1,450°C, toxic compounds such as dioxins are broken down within the rotary kiln.

●Cement manufacturing process

To begin with, the raw materials of limestone, clay, silica, and iron oxide are mixed together in appropriate component ratios and then dried and crushed in a raw-material grinder.

In this raw-material process, coal ash discharged from thermal power plants, slag discharged from steel plants, sludge from water treatment plants and sewage processing plants, incineration ash, etc. are materially recycled as alternative raw materials. This is because they contain the main cement components of calcium oxide (burnt lime), silica dioxide, aluminum oxide, and ferric oxide in good proportion.

Next, in the burning process, raw material supplied from the top of an 80-m-high preheater is made to gradually fall into a Japan-top-grade rotary kiln (diameter: 5.5 m; length: 100 m) where it undergoes chemical reactions to become clinker due to the high temperatures in the kiln (inlet: 1,000°C; outlet: 1,450°C). After exiting the kiln, it is air cooled to 120°C.

Finally, in the finishing process, gypsum is mixed in with the clinker at a ratio of about 3% and the resulting mixture is stirred and crushed in the cement mill to produce the finished product.

Among these three processes, the raw-material process performs material recycling and the burning

Plastic waste stacked inside the plant

Japan-top-grade rotary kiln Left side is in operation process thermal recycling. This is therefore a plant that performs these two types of recycling in a nearly simultaneous manner.

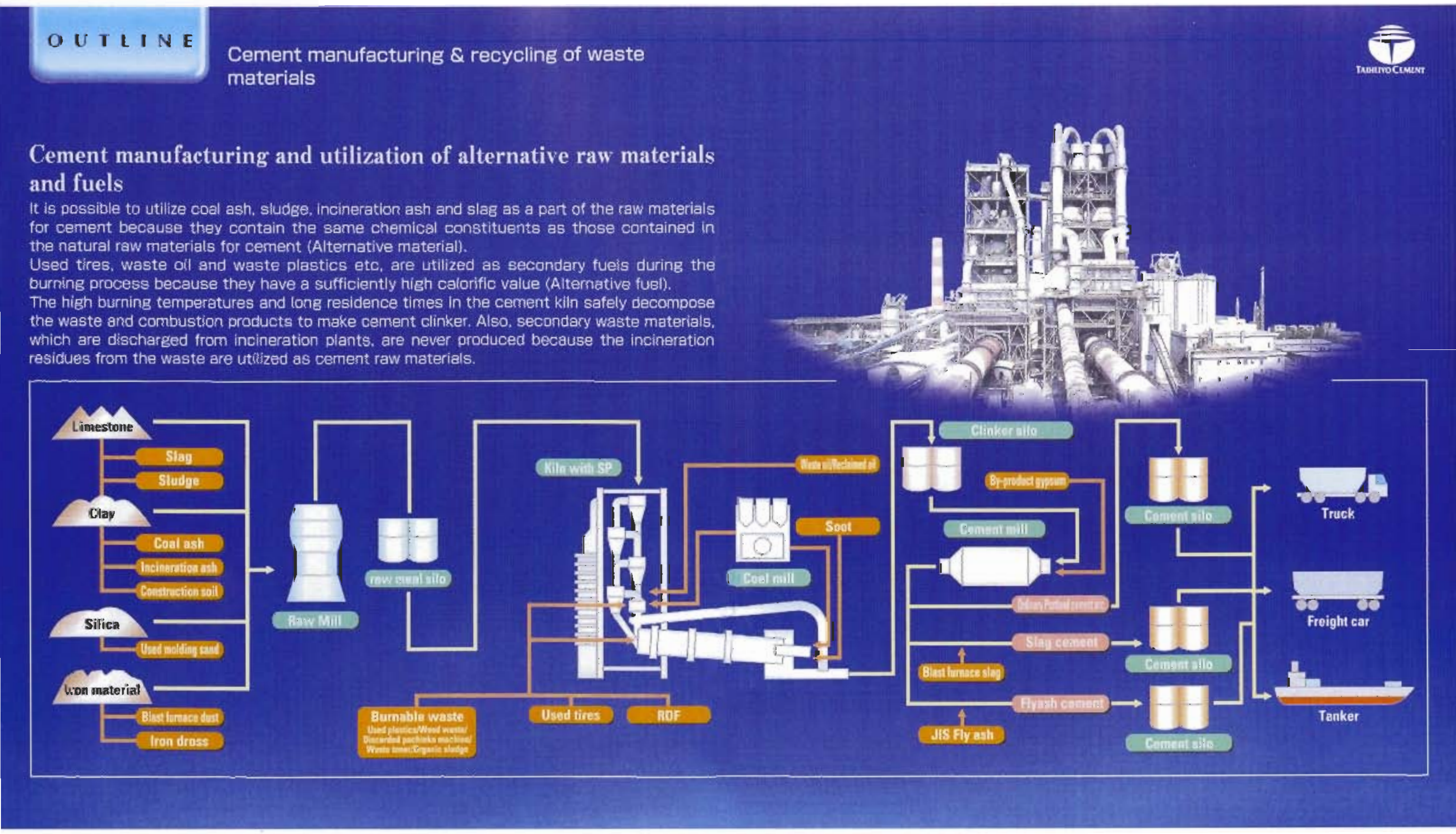
●Kumagaya Plant: Aiming for zero waste

The Kumagaya Plant has only about 100 employees despite the fact that it manufactures about 2-million tons of cement annually. This is due to a thoroughly automated and labor-saving manufacturing system.

Seventy percent of the cement manufactured at the Kumagaya Plant is ordinary cement, 10% is quick-hardening cement (used, for example, in bridge construction due to its quick-hardening and high-strength properties), and 20% is blast furnace cement (achieved by mixing blast furnace slag as a recycled material with ordinary cement and used in dam and harbor works). The main shipping format is by tank trucks that are filled with bulk cement powder for transport to ready-mixed concrete plants. Shipping of concrete in bags makes up less than 5% of all shipped cement.

Having the source of waste discharge save on natural resources and be responsible for appropriate processing expenses is said to be an important system for reducing manufacturing costs and achieving a sustainable conversion of recycled resources to raw materials and fuels. That said, it has been clearly shown that it is natural that checking be performed on a constant basis because of the accompanying social responsibility of supplying high-quality products, which may go against the idea of using plastic waste and other waste materials as recycled resources.

The aim of the Kumagaya Plant is zero emissions, and those in charge of the plant replied that controlling the generation of greenhouse gases by reducing the use of coal, extending the life of the few remaining final-disposal sites, detoxifying toxic substances, and turning as much waste material as possible back into resources is "connected to preserving the global environment and achieving a recycling-oriented society."



Cement manufacturing process flow

Generating Electric Power for 24,000 Households from Plastic Waste

Blending Fuels to Achieve a Uniform Combustion Temperature

Located in the eastern section of Tomakomai City, Hokkaido, Sanix Energy Incorporated (a wholly owned subsidiary of Sanix Incorporated) began operating the world's first thermal-recycling power plant using only plastic waste in 2003. This plant thermally recycles various types of plastic waste discharged from corporate businesses and offices.

In addition to using fuel composed entirely of plastic waste, another outstanding feature of this power plant is the generation of 74,000 kW of electric power for sale to Hokkaido Electric Power Co., Inc.

We visited Sanix Energy to learn about the original motive for constructing this power plant and the problems associated with the thermal recycling of plastic waste.

Motive for constructing power plant: "Throwing out all that plastic is a shame!"

Sanix Incorporated has 16 intermediate-processing plants throughout the country for reducing the volume of plastic waste discharged by corporate businesses and offices prior to disposing in landfills. From the beginning, it was often said that "Disposing of plastic in landfills is such a waste—can't any of it be recycled?" It was this sentiment that gave thought to the construction of a thermal-recycling power plant and that led to the birth of a power plant that uses only plastic waste as a heat source, a world's first.

At first, studies were also performed on the manufacture of RPF *1 for use as a heat source, but it was eventually concluded that producing energy directly from waste material was more effective than using additional energy to make RPF.

*1: Refuse Paper and Plastic Fuel
(High-calorie solid fuel using old paper and plastic waste as material)

Electricity from 190,000-220,000 tons of plastic waste annually

Industrial plastic waste collected at various Sanix plants is first processed to remove foreign material and then sorted mainly into flexible plastic (film and sheets). It is next crushed to fragments 150 mm or smaller in size and compressed and packaged and finally transported mostly by ship to Sanix Energy adjacent to the Tomakomai port.

View of Tomakomai power plant

Plastic waste brought to various plants from discharge sources

Criteria such as the following are used to sort plastic waste for electric power generation:

- Separate chlorine-based plastic waste and forward to specialized recycling companies
- Sort out and remove hard plastic waste
- Remove plastic waste with a high fire-retardant content (halogen, etc.), reduce its volume, and process appropriately
- Remove plastic waste with dirt, slime, etc. attached, reduce its volume, and process appropriately

In this way, 190,000-220,000 tons of plastic waste come to be used annually as fuel for generating electric power.

Obtaining a uniform caloric value from different plastic waste materials was a challenge!

Because different types of plastic waste materials exhibit different calorific values at the time of combustion, a means had to be found to obtain a uniform calorific value. In addition, a means of preventing plastic waste from becoming clogged up in fuel-delivery pipes and of delivering that waste in a stable state up to boiler injection had to be found.

The following method was adopted to solve these problems.

- Measure the combustion calorific value of each package shipped from a Sanix plant, tabulate average-calorific-value data for each plant, and make calorific value uniform by blending packages from the various plants. (Sanix original know-how)
- Specifically, blend packages using 4 preprocessing machines. For example, operate 2 machines with A-plant packages with a high calorific value and 2 machines with B-plant packages with a relatively low calorific value, adjust the flow rate of these machines to achieve the desired mixing ratio calculated using plant calorific-value data, and load the plastic-fuel supply tank.
- Use the preprocessing machines to crush the plastic waste into fragments 30 mm or smaller in size to raise flowability.
- Use compressed air (25 m/s) to simultaneously input the same amount of plastic fuel into 4 inlets on the boiler.

The above Sanix-developed technology keeps the temperature within the boiler nearly uniform enabling 24-hour continuous operation. It also reduces the load on employees that perform monitoring and operating tasks in the central control room (3-shift system).

Amount of generated electricity corresponds to power consumed by 24,000 households

The power-generating facilities adopt a circulating fluidized bed (CFB) system using silica sand (combustion booster) in the boiler's internal combustion chamber to raise heating efficiency. In

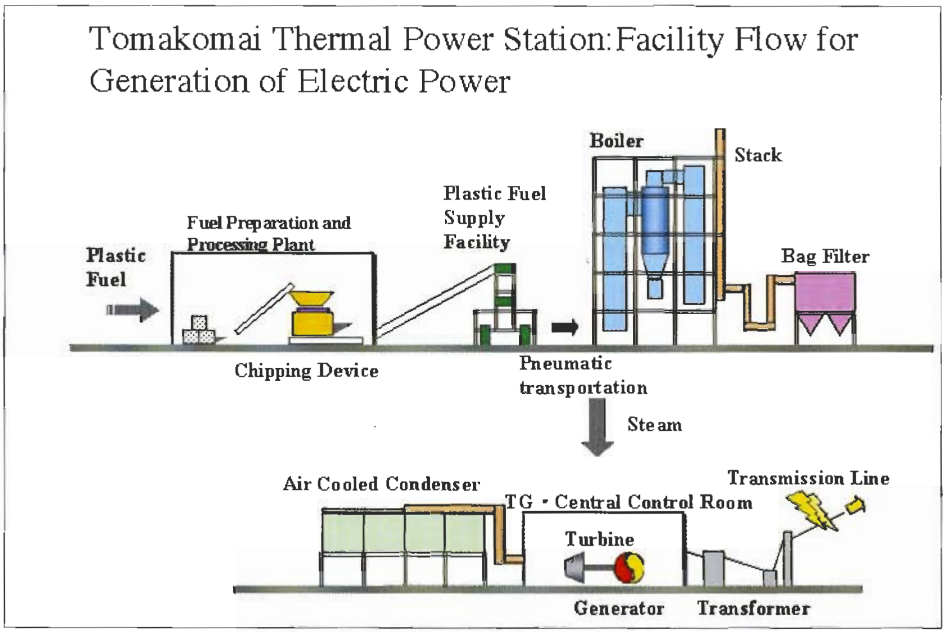
Preprocessing machines for crushing plastic waste into 30-mm-and-smaller fragments

Plastic waste brought to various plants from discharge sources addition, the steam generating equipment is designed to maximize power generation efficiency, the shape of the pipes used to feed fuel into the boiler embodies original technology, and a jet accelerator device is used to feed the fuel.

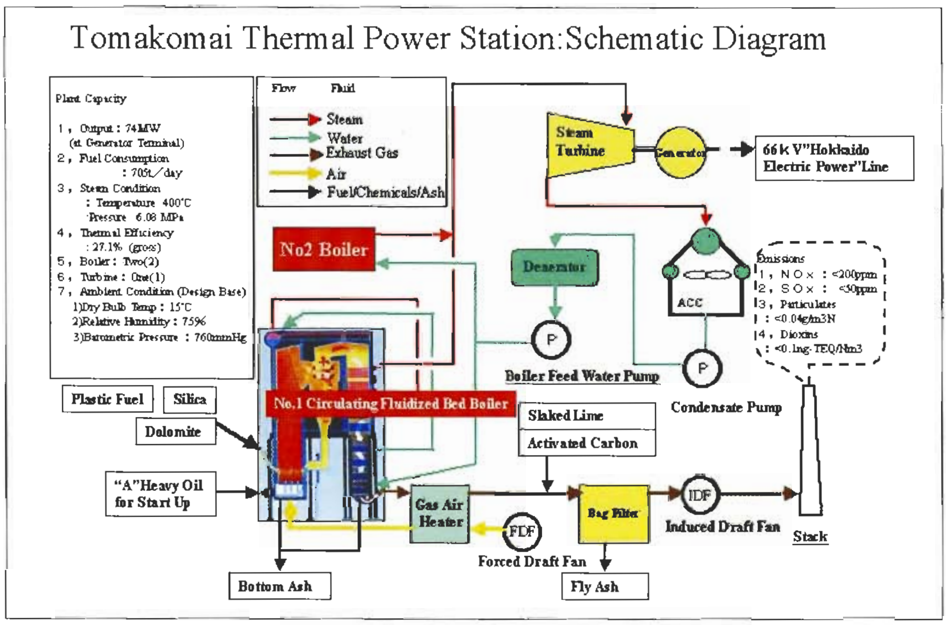
The above technical developments enable the temperature inside the boiler to be kept at 850°C or higher thereby preventing the generation of dioxins, and they enable the temperature of boiler steam to be maintained at 400°C. A high power generation efficiency of 27.1% has consequently been obtained.

At present, 600 – 700 tons of plastic waste are being used daily as fuel for the boiler.

There is one dynamo unit having an output of 74,000 kW. This corresponds to the amount of power consumed by about 24,000 households, which is perhaps the reason why this form of thermal recycling is attracting attention from around the country. About



Process flow of power-generating facilities



System flow

15% of this 74,000-kW output is used within the Sanix Energy plant itself with the remaining 85% supplied to Hokkaido Electric Power Co., Inc.

High-temperature, high-pressure steam turns the steam turbine with good efficiency, and after generating power, the system recollects the steam for reuse through an air-cooled condenser (that returns the steam to water). There is consequently no generation at all of warm waste water. The system collects ash dust with a bug filter and disposes of it together with incinerated ash in a landfill after detoxification.

Expanding processing volume to continue the venous→arterial→venous→arterial industry cycle

The thermal recycling of plastic waste can be called a "venous industry" because it recycles post-used items and waste generated by manufacturing and machining processes. The business of generating electric power, meanwhile, can be called an "arterial industry" because it reuses plastic waste and produces electric power providing part of the social lifeline essential to people's lives. In this sense, thermal recycling can be called an industry that forms a venous→arterial→venous→arterial cycle unlike any other industry.

Among the 5 million tons or so of plastic waste discharged annually from corporate businesses and offices, Sanix Energy considers about 2 million tons to be suitable for thermal recycling. At present, however, the Tomakomai power plant uses a little under 10% of that. The problem here is to determine what kind of systems and technologies should be developed for recycling the remaining 90% that is either being used for traditional waste power generation and waste thermal utilization in incineration or simply being incinerated or disposed of in landfills and not used at all.

The information was collected in the spirit of "ongoing studies to resolve thermal-recycling problems taking local conditions, transport channels, stockyards, and the local environment into account."

View of circulating fluidized bed boiler

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