Woody Biomass Cogeneration Facility in the Asphalt Mixing Factory

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ABSTRACT: Business environment for the construction industry has become tighter and tighter in these years such that the business continuation were endangered unless proper actions for preventing global warming, building a sustainable society, or cost reduction were taken. Under such circumstances, the asphalt plant of our company operates with 100% recycling of concrete debris and asphalt debris which are classified as industrial by-products and contributes for building a sustainable society.

In addition, when producing the asphalt mixture in this plant, thermal energy out of fossil fuels is used for the heating and drying process, and electrical energy for the power source. As countermeasure for global warming regarding these types of energy, this plant focused on the reuse of woody waste from construction work which is generated in larger volumes than any other industrial by-products in Tokyo metropolitan area, and installed a woody biomass cogeneration facility as the first case applied in Japan of its utilization for the operation of asphalt mixture plant, achieved supply of both thermal energy and electric energy, together with reduction of CO_2 emission.

This facility was started to be constructed from January 2006, and was completed in September, 2007, and went through its commissioning and are in full operation at present. Thus this paper reports the outlines of this plant and the woody biomass cogeneration facility installed, its main characteristics, status of operation, and issues to be tackled.

KEY WORDS: Woody Biomass, cogeneration, asphalt plant, CO_2 emission

1 INTRODUCTION

The business environment surrounding the construction industry has become more and more stringent for these few years. Unless a company takes countermeasures against the global warming, the development of the cyclic society, cost reduction etc., its business operations have become difficult to continue. In such a background, our Tokyo Integrated Mixing Factory (hereinafter called “Mixing Factory”) shows a considerable contribution toward the cyclic society by attaining 100% recycling of such debris of concrete and asphalt concrete as called the byproducts of construction.

As countermeasures against the global warming, the Mixing Factory takes advantage of heat energy and electric power energy in the process of asphalt mixture production. Among the construction byproducts, we took note of the reuse of a larger volume of wood waste produced in construction and demolition in the metropolitan area than elsewhere. For the first time in this country, we introduced in the Mixing Factory the woody biomass cogeneration facilities in an attempt to supply in combination heat energy and electric power energy through the cogeneration facilities and curtail CO_2 at the same time.

Started in January 2006, the construction was completed in September 2007, and, through trial operations and adjustments, is now in full operations. This paper reports the outlines of the Mixing Factory and the woody biomass cogeneration facilities, and their features, operation status and issues to be tackled in the future.

2 OUTLINE OF THE MIXING FACTORY

The Mixing Factory was newly built in April 2001 on that site in Shin-Suna, Koto-ku which is within a 10-km distance of Tokyo Station. An aerial view of the Mixing Factory including the woody biomass cogeneration facilities is as shown in Figure 1.

The Mixing Factory consists of three groups of facilities: the mixing facilities to produce asphalt mixture for road construction; the crushing facilities to recycle debris of concrete and asphalt concrete for recycled road base and aggregates; and the soil improvement/purification facilities in which surplus soil from construction is improved and oil-contaminated soil is purified for recycling; and, in addition, one group of the woody biomass cogeneration facilities. The composition of the biomass cogeneration facilities is as listed in Table 1.

Photo 1: Aerial View of the Mixing Factory

In the Mixing Factory, a fossil fuel (kerosene) is used as heat energy to heat and dry aggregates in the process of asphalt mixture production. Also, electric power energy is used as a power source for each device. In an effort to employ alternative energy for CO_2 reduction, the woody biomass cogeneration was introduced for the supply of electric power and heat.

The waste wood from construction and demolition serves as natural recycling energy which does not emit additional CO_2, because it stores, in the state of wood plant, CO_2 as an organic substance in its cellular structure through photosynthesis. According to the so-called Kyoto Mechanism agreed in the Kyoto Protocol, it is made a rule not to include CO_2 generated from woody fuels in the calculation of emitted CO_2. Such an emission concept is called “carbon neutral.”

Yearly energy consumptions at the Mixing Factory are about 2,800 kilo liters of kerosene and about 3,600 MWh of electric power (as recorded in 2006); therefore, their equivalent exhaust flow volume becomes about 8,500 tons of CO_2 in terms of crude oil.

Table 1: Composition of the Mixing Factory)

Factory Name	Content	Main Equipment
Asphalt Mixing Factory (8,000 m²)	Normal Hot Asphalt Mix Factory	Virgin Asphalt Mix Plant
		Recycled Asphalt Mix Plant
		Mixture Storage Silo
Crushing Factory (8,000 m²)	Recycled Asphalt Mix Factory	Supply Yard for Byproduct of Construction
		Crushing Plant
		Soil Mix Plant
		Production Yard
Soil Improvement and Purification Factory (4,500 m²)	Purification and Recycled Factory of Contaminated Soil	Supply Yard of Byproduct Soil
		Supply Yard of Contaminated Soil
		Soil Improvement Plant
		Purification Plant of Contaminated Soil
		Production Yard
Woody Biomass Cogeneration System (7,000 m²)	Reuse Factory using Woddy Fuel	Wood Chip Crushing Plant
		Supply Yard of Wood Waste
		Wood Chip Storage Yard
		Biomass Cogeneration

3 OUTLINE OF THE WODDY BIOMASS COGENERATION FACILITIES

3.1 System Configuration of the Facilities

The system configuration of the facilities is shown in Figure 1 System Flow Sheet. Their major components and specifications are shown in Table 3.

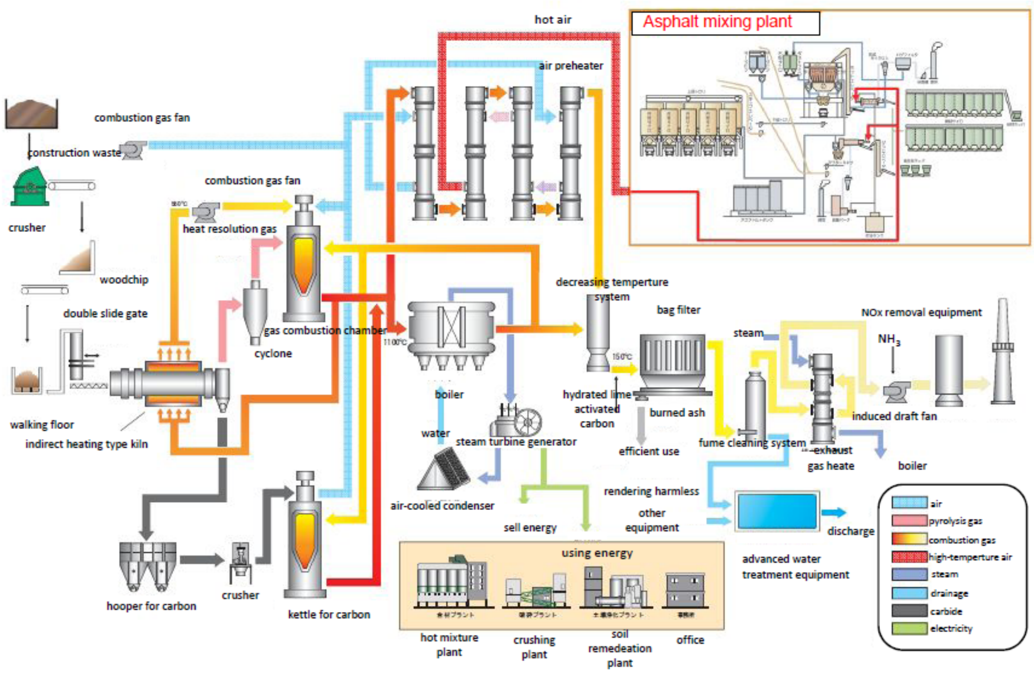

Figure 1: System Flow Sheet

Table 3: Major Components and Specifications

Component Category	Equipment	Specifications
Input supply	Crusher	Crushing capacity: about. 17 t/h (140 t/day) (at moisture contents of 15%)
Pyrolysis kiln	—	Overall length: 24,920 mm. Diameter: 2,400 mm (inside dia.)
Combustion facilities	Gas combustion chamber	Pyrolysis gas combustions & gas temperature: 3,385 kg/h & 1,100°C
		Overall length: 19,650 mm. Diameter: 3,200 mm (inside dia.)
		Gas burner: 2,290 kg-dry/h (3,385 kg-wet/h)
	Carbide combustion chamber	Carbide combustions & gas temperature: 1,131 kg/h & 1,100°C
		Overall length: 19,650 mm. Diameter: 3,200 mm (inside dia.)
		Microgrit burner: 1,131 kg/h
	Air preheater	Type & number: radiation type + shell and tube type & four units
		Preheating air flow volume: 24,000 Nm^3/h
		Temperatures at inlet & outlet: 20°C & 600°C
		Temperatures of exhaust gas at inlet & outlet: 1,100°C & 233°C
Boiler	—	Type: Natural circulation type water tube boiler
		Steam volume: about 16 t/h in maximum
		Steam pressure: 3.43 MPa
		Steam temperature: 300°C
Turbine generator	—	Type: Single cylinder, impact, geared type condensation turbine
		Output of generator: 1,500 kW
		Main steam volume: 12,100 kg/h
		Main steam pressure & temperature: 2.45 MPa & 295°C
Exhaust gas treatment	Water-spray type gas cooler	Gas volume & temperature at inlet: 26,900 Nm^3/h & about 240°C
		Temperature at outlet: about 150°C
	Bag filter	Gas treatment volume: 28,940 Nm^3/h (about 150°C)
		Dust content at inlet & dust collection efficiency: about 2 g/Nm^3 & 99%
		Filtration area: about 950 m^2
		Dust washing method: Automatic interval-set inverse washing method
	Scrubber	Gas treatment volume: 28,940 Nm^3/h
		Gas temperatures at inlet &outlet: about 145°C & 60°C
	Denitration reactor	Gas treatment volume & gas temperature at inlet: 29,480 Nm^3/h & 210°C

Of the crushing and associated devices, the crusher is provided with a lateral feeding shredder which produces uniform pin-shaped chips, and the separator provided with a rotary screen which continuously sorts over-sized chips from among shredded chips to continuously forward the shredded chips. The conveying devices consist of belt conveyors, dust collectors and a metal fragment remover.

The shredded chips stay for a short time on a walking floor of which panels are made to move one by one in a predetermined sequence. Then, those chips are hauled in a vertical direction with a bucket elevator into a charging chute. The charging chute has a sliding gate at two locations and these gates are arranged to open alternately so as to prevent air from flowing inside. These chips are charged into the pyrolysis kiln in a constant rate through a charging screw feeder.

Wood waste brought in the site is treated by the crusher to chips and is, through a feeding device, charged to the rotary type pyrolysis kiln. This kiln indirectly heats the wood chips to decompose them to pyrolysis gas (flammable biomass gas) and carbide.

Next, the combustion facilities consist of the gas combustion chamber, the carbide combustion reactor and the air preheater. The gas combustion chamber completely burns out the pyrolysis gas. Also, the generated carbon is stored in a carbon storage hopper of the carbonization facilities, where the carbide is crushed to microgrits with a carbon crusher. The microgrit-state carbide is pressure-forwarded to the carbide combustion chamber for burning out. The waste heat of combustion gas exhausted from the gas combustion chamber is transmitted to the boiler which in turn generates steam to operate the steam turbine generator, the resulting electric power being utilized within the premises. The waste heat of combustion gas exhausted from the carbide combustion chamber is heat-exchanged to hot air mainly through the air preheater, the hot air being sent for burner combustion within the premises. The water to be supplied to the boiler consists of the purified water treated from industrial water and the condensate water collected by cooling the steam used for turbine etc., both water being circulated.

For the purpose of air ventilation, such facilities are provided as for the supply of combustion air for thermally decomposed gas and as for the extraction of exhaust from combustion gas. For exhaust gas treatment, the gas is quickly cooled to 150°C with the gas cooler, is prevented from being recomposed to dioxin etc. and is detoxificated with active carbon and calcium hydroxide in the bag filter, with the fly ash collected. Such the treated exhaust gas is made to contact with sodium hydroxide-diluted water in order to neutralize and remove sulfur oxides and hydrogen chloride. Next, in the denitration reactor, the nitrogen oxides in the exhaust gas is decomposed to nitrogen and water through the catalysis action developed in the process in which ammonia water is sprayed to the exhaust gas, thus the treated exhaust gas meeting the exhaustion standard limit being released to the air.

As for waste water treatment, the waste water is subjected to aggregation, settlement and filtration processes and others, thus the treated water meeting the drainage standard limit being released to a watercourse.

3.2 Supply Volume and Properties of Wood Chips

The wood chips are supplied in a volume of 3,960 kg/h x 24 hours (about 95 tons/day). Their major properties are as shown in Table 2.

Table 2: Properties of Wood Chips

Calorific value	12,560 kcal/kg-wet
Volatile content : fixed carbon	85 : 15
Moisture content	28% (weight of free moisture in %)
Ash content	1.2% (dry weight in %)
Carbon	50.0% (weight of flammable content in %)
Oxygen	42.0% (weight of flammable content in %)
Feeding device	Not larger than 150 mm long x 30 mm thick
Bulk specific gravity of wood chips	0.2
Bulk specific gravity of carbide	0.2

4 MAIN FEATURES OF WOODY BIOMASS COGENERATION

4.1 Aspects of Feeding

The construction and demolition waste comes mostly from construction sites in the metropolitan area. Then, it is important to separate wood waste from the other. Since it often involves considerably large blocks, the shredder type crusher (Photo 2) is used.

Photo 2: Shredder Type Crusher

The wood waste of one week's stock can be piled in the material yard of the Mixing Factory. It is supplied not with an ordinary hopper feeder, but with a walking floor provided in part of the floor. In addition, in view that the wood chips at the pyrolysis kiln is heated in a low oxygen condition, the wood chips are fed at a uniform rate through the feeding chute equipped with a two-stage sliding gate, and a screw feeder.

4.2 Aspects of Burning

The Mixing Factory basically aims to operate the least wasteful, combinatory energy supply corresponding to the demand. Though the electric power energy is continuously supplied, it is sold out to the power company while the Mixing Factory has no demand.

Because the thermal energy is supplied corresponding to the operation pattern of asphalt mixing at the Mixing Factory, the waste heat output of the exhaust gas is adjusted accordingly. Such adjustment is effected in the pyrolysis kiln (Photo 3) and two combustion chambers.

The pyrolysis kiln is of an indirect heating, rotary kiln type, and its first step takes place without any oxygen supply and the second step takes place without gases to effect the carbonization.

As for the adjustment of waste heat output as one of the features of this system, the waste heat volume of a combustion gas is mainly regulated through that flammable biomass gas being burned in the gas combustion chamber (Photo 4) which is abundantly produced as a fuel in the pyrolysis kiln, and subordinately through the changing of a carbide volume supplied to the carbide combustion chamber (Photo 4). The carbide is disposed of with the crusher to microgrits for combustion in a microgrit burner to insure efficient combustion.

Photo 3: Pyrolysis Kiln

Photo 4: Left; Carbide Combustion Chamber　　Right; Gas Combustion Chamber

What is to supply hot air as means of heat energy to the Mixing Factory is the air preheater (Photo 5). It is of a shell and tube type, consists of four units and is constructed so that the exhaust gas is introduced inside the heat exchanger tube to heat the outside air to 600°C. The thermal efficiency is 60%.

Photo 5: Air Preheater

4.3 Biomass Hot Air-utilizing Burner

On the side of the Mixing Factory are kerosene burners, one each provided for new aggregates and recycled products, serving as burning sources for asphalt mixture production in the heating and drying process. These burners are arranged to control the temperature of those materials to 160 to 170°C by continuously changing the combustion rate of kerosene as a fossil fuel corresponding to the water content and supply volume of heat loads. Either burner has been operated by the use of ordinary temperature air; however, the operation mode has been changed to the use of hot air of 600°C supplied from the woody biomass cogeneration, now becoming a "Biomass Hot Air-utilizing Burner." Figure 2 shows the outlines of such conventional burner and the biomass hot air-utilizing burner.

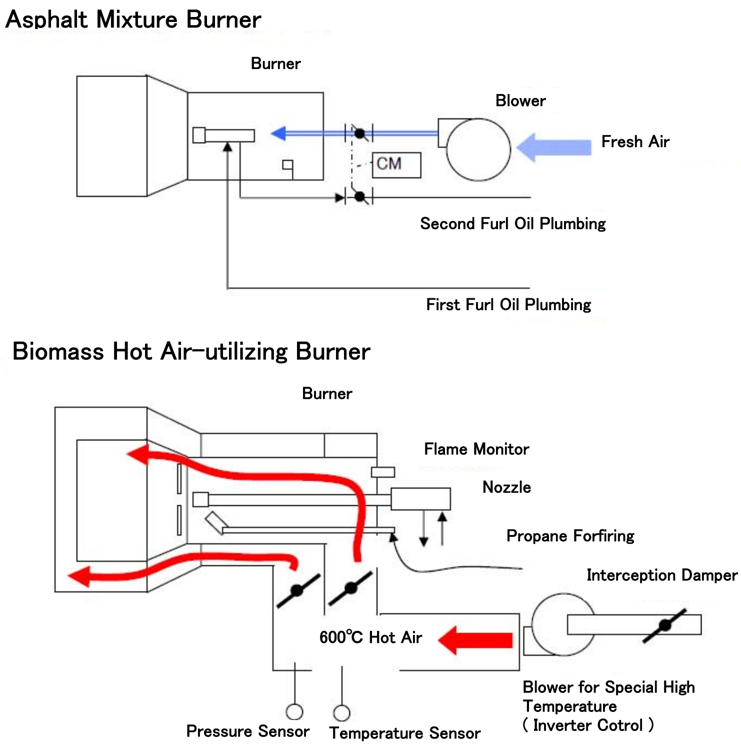

Figure 2: Outline of Biomass Hot Air-utilizing Burner

In order to improve the thermal efficiency of the conventional burner not relying on the preheated air, it seems necessary for the air volume required to burn a fuel to be reduced. It should be noted, however, that if the combustion air volume is reduced unnecessarily, the mixing condition of the fuel and air becomes unstable and is likely to cause incomplete combustion. For this reason, it is necessary for the air pressure (static) to be raised so as not to worsen the mixing condition of air and a fuel as well as the reduction of combustion air volume.

On one hand, in the case of the biomass hot air-utilizing burner assisted by the preheated air, since the exhaust air from the dryer is around 100°C, the more the combustion air volume of 600°C is increased, the more efficient the energy-saving effect is attained. On the other hand, since a bag filter and an exhauster of the exhaust gas treatment device have their own limits in the capacity, the hot air temperature and the hot air volume are regulated to the levels equivalent to those of the conventional burner. In this regulation process, an optimum level is verified by the calculation for each proposed temperature range of the preheated air to obtain the optimum hot air temperature and air volume.

4.4 Measures for Environment Preservation

With regard to the environmental measures for exhaust gases, the Mixing Factory must meet the requirements of the applicable ordinances promulgated in Koto-ward, Tokyo and therefore employs the bag filter, wet type smoke-scrubbing device (scrubber) and catalyst denitration device (denitration reactor). The exhaust gas's measurement values during the operation of the Mixing Factory and the promulgated control values are as shown in Table 4. The respective measurement values are largely below the control values.

Table 4: Measurement Values and Control Values of Exhaust Gases

Concentration	Measured value	Control value	Unit
Dust	Smaller than 0.001	0.07	g/Nm^3
HCl	1	100	ppm
NOx	45	60	ppm
SOx	Smaller than 1	10	ppm
Dioxin class	0.00045	1.0	$ng\text{-}TEQ/Nm^3$

For the waste drainage, the normal process drainage is suppressed by the reuse of the boiler blow-off water and the converse-washing water from the purification device as sprayed cooling water in the gas cooler. The drainage from the scrubber is discharged to a public sewage course only after the highly strict treatment according to the Public Sewage Discharge Standard. As for the vibration and noise, the site is within the exclusive industrial area and is therefore free of any control, but complies on a voluntary basis with the control requirements for Class 2 Industrial Area. On the stench, the measured value is below a stench index of 30.9 which is established as control limit for the Tokyo Metropolitan Government.

4.5 Energy Saving and Reuse of Resources

The operation of the biomass cogeneration facilities totals to 320 days, except for the yearly maintenance period, and yields the electric power supply of 3,200 MWh for the Mixing Factory which is equivalent to 800 liters of crude oil.

As for the thermal energy, hot air is supplied to the Mixing Factory at an hourly rate of 18.9

GJ. Since the plant operates in a total of about 2,100 hours, an eventual saving totals to some 40,000 GJ. The equivalent crude oil saved thereby is 1,000 kilo liters. Accordingly, a total CO_2 reduction reaches 3,900 t-CO_2, thus a reduction ratio becoming 46%. This reduction ratio is accredited as AA according to the Global Warming Countermeasure Scheme for the Tokyo Metropolitan Government.

Also, the ashes to which the carbide, namely burnt wood, has been burned contain phosphorus, potassium, calcium etc. These ashes can be utilized as lightweight soil particles for rooftop garden planting by palletizing them together with microgrits. This is to say that the ashes also can be reused.

5 OPERATION STATUS AND FUTURE ISSURES

The biomass cogeneration facilities were completed in September 2007, and, through trial operations for six months, put into the planned regular operation for one year from April 1, 2008. By virtue of many things having been trial-based, unexpected troubles occurred at various points, so that the full operation hours could not exceed 240 days, with the electric power supply staying at 60% and the thermal energy use at 10%. As compared with the planned operation ratio of 46%, the actual operation stayed at 33%.

Conceivable future improvement measures to assure more stable heat and power supply from the cogeneration than ever are to properly adjust the charging volume of wood chips by taking account of their varying water content; to improve insufficient gas feeding in the pyrolysis kiln; and, to reduce the heat radiation by improving the heat retentiveness of equipment ducts and others. In addition, to derive a maximum benefit of the heat use, the present intermittent daily operation on the side of the Mixing Plant should be improved toward the real continuous operation, for which purpose it is essential to try to keep a continuous operation by insuring the effective use of storing facilities, the proper sequence of production and shipment, and the patterned mode of operation.

6 CLOSING REMARKS

As the cyclic society develops, to recycle, reuse and reduce the byproducts of construction must be on a steady increase. Our Mixing Factory initially started the 100% recycling of concrete and asphalt debris, and subsequently proceeded to the 100% recycling of surplus soil from construction and demolition and oil-contaminated soil.

Now, with the introduction of the woody biomass cogeneration, its facilities have newly proceeded to the reuse of surplus construction lumber to contribute not only to further development of the cyclic society, but also to the decrease in CO_2 for the global warming-countermeasures as well. In addition, if the biomass cogeneration facilities are further improved in efficiency, it will lead to the cost reduction and the reducing. All players of the Mixing Factory are prepared to improve the facilities so that all thermal energy produced by this biomass cogeneration could be 100% utilized in the Mixing Factory.

All of us would like to express our cordial thanks to all the parties who did not spare every effort for the construction.

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