Development of a Manufacturing System in Production of Asphalt Mix for Effective Usage of Wooden Tar

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ABSTRACT: In today's situation that the global warming issue due to usage of fossil fuels becomes a serious problem, it is necessary for the construction industries to present countermeasures for the issue. Especially for the road construction industry, fossil fuels have been consumed and a large amount of CO_2 has been emitted for the production of the asphalt mix. Then the authors present a result of building the system of stably utilizing wooden tar generated as a by-product from a wooden biomass gas power plant utilizing chips of lumbers from thinning and pruning.

A burner technology of asphalt mix production that uses wooden tar at 90% and heavy oil at 10% was developed. The burner system that consists of double-fuel burner for wooden tar and single-fuel burner for heavy oil keeps stable burning. The high quality of the asphalt mix product using wooden tar was verified. The new system of the asphalt mix production using wooden tar follows the environmental regulations about emission gases.

In the case of wooden tar at 90% and heavy oil at 10%, the CO_2 emission factor for production of recycled asphalt mix was able to be reduced by around 60%, and the CO_2 emission factor for only the fuel at production was able to be reduced by around 80%.

KEY WORDS: Wooden tar, asphalt mixture, CO_2 emission, low carbon

1 INTRODUCTION

The carbon dioxide emission of which source is burnt fuel in Japan reached 1.186 billion ton in 2006 and it exceeded 1.059 billion ton, which is the carbon dioxide emission of the base year of Kyoto Protocol (1990), by 12%. Out of this number, the carbon dioxide emission from the industrial section slightly decreased from 389 million ton in 1990 to 387 million ton in 2006, but the industrial section emitted the largest amount of carbon dioxide among all sections and countermeasures are necessary to be taken as it had been done so far.

The carbon dioxide emission attributed to the construction industry out of the industry section is estimated to be 24%, or 93 million ton. The emission from the civil project is estimated to be 10% out of it, or 9.3 million ton, and the emission from projects related to road is estimated to be 25% out of it, or 2.33 million ton. The emission from projects related to road is the largest portion in the civil projects.

In addition, most of the carbon dioxide emission from the road-related projects is considered to be related to asphalt mixes in the paving work. Then reduction in the carbon dioxide emission from production of the asphalt mix is an effective measure in civil and building construction industries.

As Tokyo metropolitan government will enforce "Duty of Reducing Total Emission of Green House Effect Gases and Emission Trading System" in 2009, further reduction in the carbon dioxide emission will be required in near future.

This paper explains a new system of utilizing wooden tar as an alternative to fossil fuel that has usually been used, as a countermeasure to reduce the carbon dioxide emission from the production of asphalt mix. The wooden tar to be utilized is the one generated as a by-product from the gasification plant of woody biomass, and a facility in which this wooden tar can be burned stably was developed. Evaluation on its burdens on the environment, effects of reduction in the carbon dioxide emission, and economical effects induced by this system was carried out.

2 CURRENT STATUS OF ASPHALT MIX PRODUCTION

In the production of asphalt mix, either asphalt mix made of virgin raw material, or recycled asphalt mix produced by recycling the existing pavement, a large amount of fossil fuel has been consumed for heating and drying of aggregates.

In Japan, around 50 million tons of asphalt mix was produced per year, and fuel equivalent to 500 thousand kiloliters of heavy fuel oil A was consumed and 1.38 million tons of carbon dioxide was discharged for heating and drying aggregate or recycled aggregate. This consists of 40% of total carbon dioxide emission from the road-relating industry.

3 PRODUCTION OF ASPHALT MIX UTILIZING WOODEN TAR

In Nishi-Tokyo asphalt plant of Maeda Road Construction Co., Ltd. (located in Hachioji, Tokyo), 250 thousand tons of asphalt mix has been produced and shipped annually. In the plant, asphalt mix has been produced by heating and drying aggregate by using heavy fuel oil A , the carbon dioxide emission in the production amounts to as large as 6,000 tons per year.

Then a system in which consumption of fossil fuel was reduced by using wooden tar as an alternative to heavy fuel oil A and the carbon dioxide emission was reduced, was developed.

3.1 Power Generation by Wood Biomass Gasification and Wooden Tar

(1) Power Generation by Wood Biomass Gasification

The wooden tar generated at the woody biomass gasification plants being operated at Yamagata Green Power Station and at Ishikawa Green Power Station which are owned by Japan Biomass Development Co. Ltd. (Head office at Chiyoda-ku, Tokyo), was utilized.

At these two power plants, woody biomass produced from raw material of thinned and clipped wood generated from local woods, is utilized in an up-drought type gasification furnace to execute gasification power generation. In this power generation process, total 8.0 ton/day of wooden tar is generated as by-product (Table 1). In the biomass gasification power generation, there was a problem of the disposal cost of the wooden tar generated daily. But if looked differently, wooden tar is stably generated when the power plant is operated. Then a system to utilize this wooden tar as woody bio-fuel, was built.

Table 1: Outline of Biomass Gasification Power Plant

Name of facility	Yamagata Green Power Co., Ltd.	Ishikawa Green Power Co., Ltd.
Location	Murayama City, Yamagata Pref.	Hakui County, Ishikawa Pref.
Capacity of woodchips Treatment	60 t / day	69 t / day
Power Generation Capacity	2,000 kW (maximum)	2,500 kW (maximum)
Discharged amount of Wooden Tar	3.7 t / day	4.3 t / day
Completion Date	Jan. 2007	Feb. 2008

(2) Wooden Tar

The wooden tar exists as a volatilized state in a combustible gas during thermal decomposition of woodchips in the gasification furnace, and is collected by condensation together with water vapor in the gas at the cooling stage. By separating by specific gravity the condensate containing wooden tar, wooden tar and wood acid are separated and wooden tar having heavier specific gravity is recovered from the bottom.

Physical properties of a representative wooden tar contained in the generated wooden tar was measured and shown in Table 2 together with that of heavy fuel oil A. The properties of wooden tar vary significantly depending on its production method and the type of wood to be used as its raw material.

Table 2: Physical Properties of Representative Wooden Tar and Heavy Fuel Oil A

	Specific Gravity	Kinematic Viscosity	Water content	Lower Heating Value	
	—	mm^2/s	%	kcal/kg	kcal/liter
Wooden Tar	1.1270	36.4	7.05	6,600	7,483
Heavy Fuel Oil A	0.8419	2.12	0.00	10,230	8,613

Wooden tar is a sticky oily substance of brown to black color generated in general by thermal decomposition of organic compounds. Different compounds of various natures such as water-soluble tar derived from hemicellulose or cellulose, or water insoluble tar derived from lignin, are generated depending on its thermal decomposition temperature. Since the wooden tar used in this study has its thermal decomposition temperature at approximately not higher than 700℃, it is considered to be composed mostly of water-soluble tar (Tsutsumi, 2006). Therefore, as wood acid is dissolved in the wooden tar, separation by specific gravity cannot proceed rapidly because of little difference in both specific gravities. Thus water content in the wooden tar produced is not constant.

As this study uses wooden tar generated from two sources of gasification power plants in Yamagata Pref. and Ishikawa Pref., large difference in water content (6.52 – 12.05%) was generated even with the same production method of wooden tar. Since the heat generation becomes lower as water content in wooden tar becomes higher, it will become an issue for obtaining stable heat quantity.

Then, as water content in wooden tar varies by each specimen of wooden tar, variations are also observed in the relationship between temperature and viscosity. Therefore when wooden tar is supplied at constant rate by the pump as fuel and is transferred to the burner to be burned, the condition of burning becomes unstable if the same burning method as that for conventional fossil fuel is taken. As shown above, wooden tar cannot necessarily be said as a stable fuel and development of new burning equipment has been required.

3.2 Development of Burning Equipment

In order to burn wooden tar at stable conditions, as there were troubles took place such as unstable burning, or accidental fire with conventional burners, development of a new burner for burning wooden tar was conducted.

For the burner used for the drying furnace with which drying and heating of aggregates and others is done in the conventional production plant of asphalt mix, diffusive burning is adopted as the basic principle. Diffusive burning is that burning continues in the region where the mix proportion of fuel gas and air, i.e. oxygen becomes optimal during the process of fuel transforming to air and dispersing. The burning rate at this time is governed by the diffusion rate of the fuel gas. As explained, in order to burn a liquid fuel, it has to be gasified and mixed with the optimal amount of air, various methods to gasify the liquid fuel have been devised depending on those purposes and realized as burners.

The burner generally used in the production plant of asphalt mix, adopts the diffusive burning principle, in which the liquid fuel is sprayed from the nozzle to fine particles for easy gasification and is mixed with air required for burning, and the gasification is promoted by fire balls formed in the premix chamber at the tip of the burner as shown in Figure 1, and a stable burning condition is achieved. In order to gasify the liquid fuel smoothly, thermal energy equivalent to the vaporization heat of the liquid fuel must be given to the fuel. In this burner, heating is performed by spraying mist-like fuel into fire balls (fire source) formed in front of the spray nozzle. A negative pressure region is generated in front of the diffuser caused by the stream of fuel air created in the layout of the diffuser and the premix chamber, and the fire balls are formed by the gasified fuel being dragged into this negative pressure region. The diffuser is for forming the fireballs stably, and is of such a shape that adhesion of soot or deformation due to heat is difficult to occur. The premix chamber is for mixing the gasified fuel by passing the fire ball zone with the burning air, and is made to form frame appropriate for the asphalt plant by devising its section shape.

As wooden tar has relatively higher viscosity than heavy fuel oil A, the discharge pressure of the fuel pump is raised in order to spray from the nozzle to promote gasification. In addition, by making the premix chamber to be fire-proof insulation structure as shown in Figure 2, the fireballs are devised to become large and to be kept at high temperatures. But when the water content of the wooden tar increased and became less viscous because of the reasons such that wood acid is mixed in the wooden tar, troubles that accidental fire occurred because of a bad mist condition due to failure to increase discharge pressure, took place frequently. Then, in order to spray stably by not being affected by its viscosity, the nozzle for spraying fuel was changed from single-fluid-spray type to the double-fluid-spray type as shown in Figure 3. This is the type in which wooden tar and compressed air for the compressor are supplied together to the nozzle and are sprayed to a mist condition. With this method, stable burning was able to be achieved regardless of the water content in the wooden tar. The single-fluid-spray type is a method in which liquid fuel is pressurized by a pump to form a mist state, and the double-fluid-spray type is a method in which fuel is transformed into mist with the energy of compressed air. Although this method consumes more power for compressing air, efficiency in forming a mist state from the fuel oil is superior with the double-fuel-spray method.

In addition, by installing two nozzles, i.e., a double-fluid nozzle to spray wooden tar and a single-fluid nozzle to spray heavy fuel oil A, and by adopting control system to be able to set at any supply rate of each fuel separately, a more stable combustion system that can be adjusted for the supplied state and quality of the wooden tar, was successfully constructed as shown in Figure 4. By the nozzle including attached piping circuits for wooden tar being completely separated from those for heavy fuel oil A as explained above, condensation phenomenon caused by mixing wooden tar and mineral oil can be avoided, and moreover, even if any trouble happens in the pipe circuit for the unstable wooden tar side, operation can be continued only with heavy fuel oil A. For normal operation, it is possible to burn 100% of wooden tar but by not less than 10% by calorie ratio of heavy fuel oil A being burned together, combustion of wooden tar is found to be stabilized. Therefore when maximizing utilization of wooden tar, burning of a mixture of 90% by calorie of wooden tar and 10% by calorie of heavy fuel oil A have been performed.

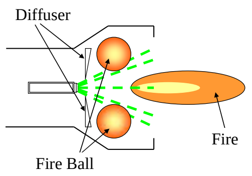

Figure 1: Conventional Type Burner

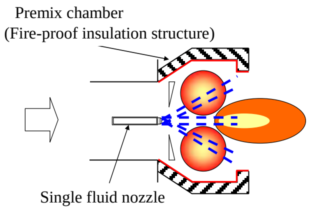

Figure 2: Installation of Single-Fuel Nozzle

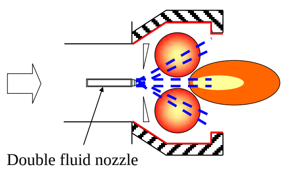

Figure 3: Installation of Double-Fuel Nozzle

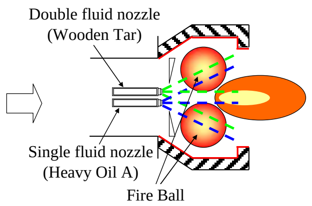

Figure 4: Installation of Single-Fuel and Double-Fuel Nozzles

3.3 Transportation System for Wooden Tar

In this system, woody biomass originated from the woods in rural regions is utilized in city region. As woody biomass shall be transported from Yamagata Pref. or Ishikawa Pref. to Tokyo Metropolitan District (Hachioji city) in the system, it is important to build an effective transportation system. Table 3 shows the comparison of heat quantities in the volume that can be transported by one trip for wooden chip and for wooden tar. It can be seen that the amount of not less than three times as large energy with wooden tar can be transported by one trip as that with woodchips. The wooden tar generated as by-product from gasification power generated used in this system has larger energy density than woodchips and has more suitable form for long distance transportation.

Table 3: Transportable Energy for Woodchips and Wooden Tar

	Heat quantity	Unit mass per volume	Maximum Load Capacity for 10 ton Vehicle	
			Volume or mass	Energy
Woodchips	10.05 MJ / kg (2,400 kcal / kg)	0.2 t / m^3	40 m^3 (dump truck)	80,400 MJ (19,200 Mcal)
Wooden tar	27.63MJ / kg (6,600 kcal / kg)	1.12 t / m^3	10 ton (tanker)	276,300 MJ (66,000 Mcal)

4 VERIFICATION OF EFFECTS

4.1 Loads on Environments

(1) Measurement of Smoke

For the exhaust gas discharged at the production of asphalt mix by using wooden tar as fuel, measurement of the smoke was conducted and the results compared with measured values of exhaust gas from conventional heavy fuel oil A are shown in Table 4. There is no large difference from the exhaust gas of the case when heavy fuel oil A is used, and all items regulated by the Air Pollution Control Law satisfied the required limits.

Table 4: Measurement Results of Exhaust Gas

Fuel used			Wooden tar		Heavy fuel oil A	
Measurement item		unit	Measured value	Limit value	Measured value	Limit value
Exhaust gas volume	Wet	m^3N/h	39,600	—	38,900	—
	Dry	m^3N/h	38,300	—	37,700	—
Dust or Soot	Concentration	g/m^3N	0.112	—	0.148	—
	On*=Os*	g/m^3N	0.112	0.5	0.148	0.5
	Concentration	ppm	34	—	32	—
NOx	On=16%	ppm	52	230	51	230
	On=0%	ppm	219	—	214	—
SOx	Concentration	ppm	2	—	2	—
	Emission volume	m^3N/h	0.061	9.16	0.058	8.68
HCl	Concentration	mg/m^3N	4	(80)	3	(80)

*: On is standard Oxygen concentration and Os is measured Oxygen concentration.

(2) Hazardous Substances in Smoke

Hazardous substances in the smoke generated at burning wooden tar were confirmed. For the quantification of hazardous substance in the smoke, composition analysis of the representative wooden tar shown in Table 2 was conducted at first. Based on the results of composition analysis shown in Table 5, the amount of dry exhaust gas generated when 1 kg of wooden tar is burned was calculated, and the contents of hazardous substance in the wooden tar was analyzed, thus mass concentration of hazardous substance in the smoke was calculated. The amount of dry exhaust gas for each composition calculated is shown in Table 6.

Table 5: Composition Analysis Results of Wooden Tar Unit: %

Residual carbon	Water (H_2O)	Carbon (C)	Hydrogen (H)	Nitrogen (N)	Sulfur (S)	Oxygen (O)	Total
15.98	8.8	66.44	7.31	0.96	0.04	0.47	100

Table 6: Component Concentration in Exhaust Gas and Dry Exhaust Gas Volume
(Unit : m^3N)

CO_2	H_2O (water)	H_2O (hydrogen)	NO	SO_2	Dry exhaust gas volume
1.539	0.045	0.811	0.015	0.00028	10.35

Next, as there is significant effect of co-existing organics when analyzing hazardous substances contained in wooden tar, it is important how to transform the target substances to be less impacted by physical and chemical effects and to be analyzed. This time, as the pre-treatment of ICP emission spectrometry, decomposition by perchloric acid and nitric acid in accordance with the test method for industrial wastewater was used, and for the hazardous substances on which the test is not applicable, tests were conducted in accordance with the tests method for sediments, and for fluorine, direct distillation method in accordance with the test method for industrial wastewater. The results of hazardous substance measured in wooden tar and in the smoke are as shown in Table 7. The emission in the smoke is calculated by the (contents/dry exhaust gas volume).

For the results of the calculation, it is estimated that hazardous substances in the smoke shall satisfy the discharge limit values for all the items to be regulated.

Table 7: Estimated Emission of Hazardous Substance in Smoke

Measurement item	Contents (mg/kg)	Limit contents (mg/kg)	Emission (mg/m^3N)	Limit emission (mg/m^3N)	Quantification Method
Cd	0.1	Not more than 150	Less than 0.01	1	***
Total Cr	0.3	Not more than 250	0.024	0.25	***
Cyanide compounds	14	Not more than 50	1.1*	6**	14.1,Notification No.127****
Total Hg	Less than 0.01	Not more than 15	Less than 0.001	—	5.1.2,Notification No.127****
Se	Less than 0.1	Not more than 150	Less than 0.01	—	8(ICP),Notification No.127****
Pb	0.9	Not more than 150	0.07	10	***
As	0.5	Not more than 150	0.04	0.05**	8(ICP),Notification No.127****
F	Less than 25	Not more than 4000	Less than 2	9	JIS K 0102 34.1 (direct distillation)
B	5.6	Not more than 4000	0.44	—	***
Cu	4.4	Not more than 125	0.35	—	***

* : calculated without consideration on thermal decomposition
** : applicable to facilities other than smoke emitting facilities
*** : Perchloric acid decomposition – ICP emission spectrometry
**** : MOE, waste water management,1988

(3) Odor of Exhaust Gas from Wooden Tar Burning

Although wooden tar has an odor specific to tar, when it is burned as fuel, there is no such odor smelled in the exhaust gas from its combustion. As a reference, trial combustion of wooden tar using the pilot plant was carried out and the odor concentration was measured, of which results are shown in Table 8.

As this system is located in the third class zone (industrial district), the limit values in accordance with the Offensive Odor Control Law and with the Tokyo Metropolitan Environmental Security Ordinance are calculated .As the actual height of emission outlet is 30 m, the odor emission rate is calculated to be 494,000 m^3N/min, which is applied as the limit value. The results of the odor concentration measurement at the pilot plant are shown in Table 8. The odor emission rate is 351,000 m^3N/min, which is satisfies the limit values.

Table 8: Odor Measurement Results of Exhaust Gas from Wooden Tar

Odor Index	Odor Concentration	Odor Emission Rate (m^3N/min)
27	550	351,000 (limit value：494,000)

4.2 Quality Confirmation of Asphalt Mix

In order to confirm the quality of the asphalt mix produced by using wooden tar as fuel, Marshall stability test and the wheel tracking test were conducted on the asphalt mix produced (dense graded asphalt mix by using straight asphalt) in the cases of using wooden tar as fuel and heavy fuel oil A, and the physical properties for both cases were compared (Table 9).

For the physical properties, those are not different from the standard values in the case with heavy fuel oil A and satisfy the limit values for all items, and thus the quality as the asphalt mix is not considered different.

Table 9: Physical Properties and Dynamic Stability of Asphalt Mix

	Density (g/cm^3)	Porosity (%)	Degree of Saturation (%)	Marshall Stability (kN)	Flow Value (1/100cm)	Dynamic Stability (times/mm)
Limit values	—	3～6	70～85	Not less than 7.35	20～40	Not less than 500
Standard	2.386	3.6	77.2	12.37	32	830
Wooden Tar used	2.383	3.8	76.6	13.64	34	860

4.3 Effects of Reduction in Carbon Dioxide Emission

In order to study effects of reduction in the carbon dioxide emission for the asphalt mix using wooden tar as a fuel, for the production of recycled dense grade asphalt mix (13) which is most generally applied, a case that wooden tar and heavy fuel oil A is used at 9:1 ratio by calorie and a case that heavy fuel oil A is used by 100% were compared. For both cases, the temperature at production was set at 160°C and the daily production rate was set as 800 ton, for the trial calculation. The results are shown in Table 10. The carbon dioxide emission factor for each component material, fuel, and power for the production of the mix are referred to the reference (JRA, 2008). For the carbon dioxide emission factor for the transportation of wooden tar, it is calculated based on the actual transportation distance (450 km).

By substituting heavy fuel oil A with wooden tar as fuel, emission of carbon dioxide generated at the drying and heating process of aggregate and others in the production of the asphalt mix, can be significantly reduced. As a result, for the case that wooden tar of 90% by calorie is used as fuel, the carbon dioxide emission factor for the sum of the emission at raw material production of the recycled asphalt mix and that of the fuel (including fuel for the transportation of wooden tar) for its production was reduced by approximately 60%, and for the carbon dioxide emission for only the fuel at the production excluding those for material production, it was reduced by approximately 80%.

Table 10: Calculation of CO_2 Emission Factor for Asphalt Mix Using Wooden Tar

		The case using Heavy fuel oil A 100%	The case using, Wooden tar 90% : Heavy fuel oil A 10%	Reduction Rate
		Recycled dense grade asphalt mix	Low carbon recycled dense grade asphalt mix	(%)
Raw material	Emission (kg-CO_2)	7,428.62	7,428.62	—
Production	Emission (kg-CO_2)	20,730.98	3,691.51	
Subtotal	Emission (kg-CO_2)	28,159.60	11,120.13	
CO_2 emission factor (kg-CO_2/t)		35.20	13.90	60.5
CO_2 emission factor originated from fuel consumption (kg-CO_2/t)		25.91	4.61	82.2

4.4 Economical Effects

Considering the cost aspect of using wooden tar as a fuel, as it is generated as a by-product from the woody biomass gasification power plants, the purchase cost can be reduced. The wooden tar used in this system is set to have the same price as heavy fuel oil A that fluctuates in conjunction with the oil price. In this manner, the asphalt mix can be produced nearly at the current price, and moreover, carbon dioxide emission can be reduced. This system will be started in Tokyo Metropolitan Government from the fiscal year 2009. When the emissions regulation and emissions trading such as “Duty of Reducing Total Emission of Green House Effect Gases and Emission Trading System” become popular in actual jobs, the economical efficiency of this system is considered to be further improved.

As indicated by the figures shown in Table 11, even if the unit cost per volume is set equal for wooden tar and for heavy fuel oil A, heat quantity of wooden tar is smaller than that of heavy fuel oil A and thus the amount to be burned will become increased. However, if the value for the reduction of carbon dioxide emission of 21 yen/liter is accepted by such a form as Green Heat Certificate for example, the economical efficiency will be improved and the economical effects by using wooden tar as fuel will become larger.

Table 11: Economical Efficiency of Wooden Tar and Heavy Fuel Oil A

	Heat Quantity	Volume equivalent to heavy oil A of 1 liter	Unit cost (including transportation fee)	Price equivalent to heavy oil A of 1 liter	Value for reduction of CO_2	Price including carbon value
	kcal/liter	liter	yen/liter	yen/liter	yen/liter	yen/liter
Wooden tar	7,348	1.2	45	54	21	33
Heavy fuel oil A	8,613	1.0	45	45	—	45

The value for the reduction of carbon dioxide emission is calculated by referring to the price under the current RPS law as follows.

As a general electric power company discharges 0.555kg-CO_2 carbon dioxide per 1kwh electricity generation, if electricity generated by new energy is used, this is equivalent to reduce 0.555kg-CO_2 carbon dioxide per 1kwh electricity generation. When 1 liter of wooden tar is considered to substitute for 0.85 liter of heavy fuel oil A in terms of heat quantity, the carbon dioxide emission that 1 liter of wooden tar reduces becomes 2.3032 kg-CO_2/liter, which is 85% of the carbon dioxide emission from combustion of heavy fuel oil A, 2.7096 kg-CO_2/liter. Since the value for new electric energy is approximately 5 yen/kWh under the year 2008 version of the RPS law, approximately 5 yen per 1kWh of electricity is assumed to be able to reduce 0.555 kg-CO_2 of carbon dioxide. Therefore as 1 liter of wooden tar can reduce 2.3032 kg-CO_2/liter of carbon dioxide emission which is about four times as much as that reduced by the electricity, the value for the carbon dioxide emission is calculated to be 21 yen/ liter.

4.5 Shipping of Low Carbon Asphalt Mix

This system has been introduced into the Nishi-Tokyo asphalt mix plant since September, 2008. 306 kiloliter of wooden tar was used as fuel by September, 2009 and 99,592 ton of asphalt mix was produced and sold. The workability at construction was satisfactory and there has been no problem occurred so far with regard to its service condition.

The asphalt mix produced was named as “Low Carbon Asphalt Mix”, in which the price and quality of the conventional asphalt mix was maintained and the carbon dioxide emission was reduced by producing with wooden tar. And we performed PR activities widely to governments, project owners, and neighboring residents that the road construction was performed with utilizing the Low Carbon Asphalt Mix, and performed promotion activities of the road construction with reduced environmental burdens, public awareness of infrastructure development, and activities for preventing global warming.

5 CONCLUSIONS

In this paper, development of the new system utilizing wooden tar as a substitute for fossil fuel as countermeasure of reducing the carbon dioxide emission at production of the asphalt mix, and its evaluation was explained. Major outcomes are summarized as follows.

1) A system in which wooden tar generated from the biomass gasification power generation is transported by taking advantages of high energy density of the wooden tar, and is utilized for stable production of asphalt mix, was developed.
2) A technology to produce asphalt mix stably by utilizing wooden tar was developed. By combination of the double-fuel burner suitable for wooden tar and the single-fuel burner, stable burning condition was obtained. By using wooden tar at 90% by calorie ratio, a stable combustion was achieved.
3) The asphalt mix produced was verified to have no problem to be a product. For the wooden tar used in this system of which raw material is thinned and clipped wood generated from the woods, the wooden tar itself and the smoke generated by its combustion were confirmed to satisfy the environmental regulations.
4) In case when the wooden tar of 90% by calorie ratio is used as fuel, compared with the case when heavy fuel oil A at 100% is used, the carbon dioxide emission factor related to the production of recycled asphalt mix can be reduced by around 60%, and the carbon dioxide emission factor related only to the fuel used for the production of the same mix (including fuel for transportation of the wooden tar) can be reduced by around 80%.
5) Even the unit price per unit volume of wooden tar is set to be the same as that of heavy fuel oil A, its heat quantity is less than that of heavy fuel oil A and a larger amount is needed to be burned to maintain the same heat quantity. However, the value for the reduction of carbon dioxide emission for the wooden tar can be estimated as around 20 yen per 1 liter of the wooden tar by referring to the environmental value under the current RPS law, and thus its economical efficiency is improved.

By producing asphalt mix with wooden tar fuel as explained so far, reduction in the carbon dioxide emission from the asphalt mix production plant and reduction in the production cost are considered to be achieved. In addition, through the road construction by utilizing the Low Carbon Asphalt Mix, we would like to appeal widely to the people how a new style of infrastructure development should be.

Regeneration and maintenance of the woods are important issues for Japan in the future. Under this context, this system in which wooden tar made of thinned wood as raw material is utilized as alternative fuel to fossil fuel, is able to enhance the environmental value of thinned and remaining wood and to become an useful resource, which is considered to be one of the means leading to regeneration and maintenance of the woods.

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