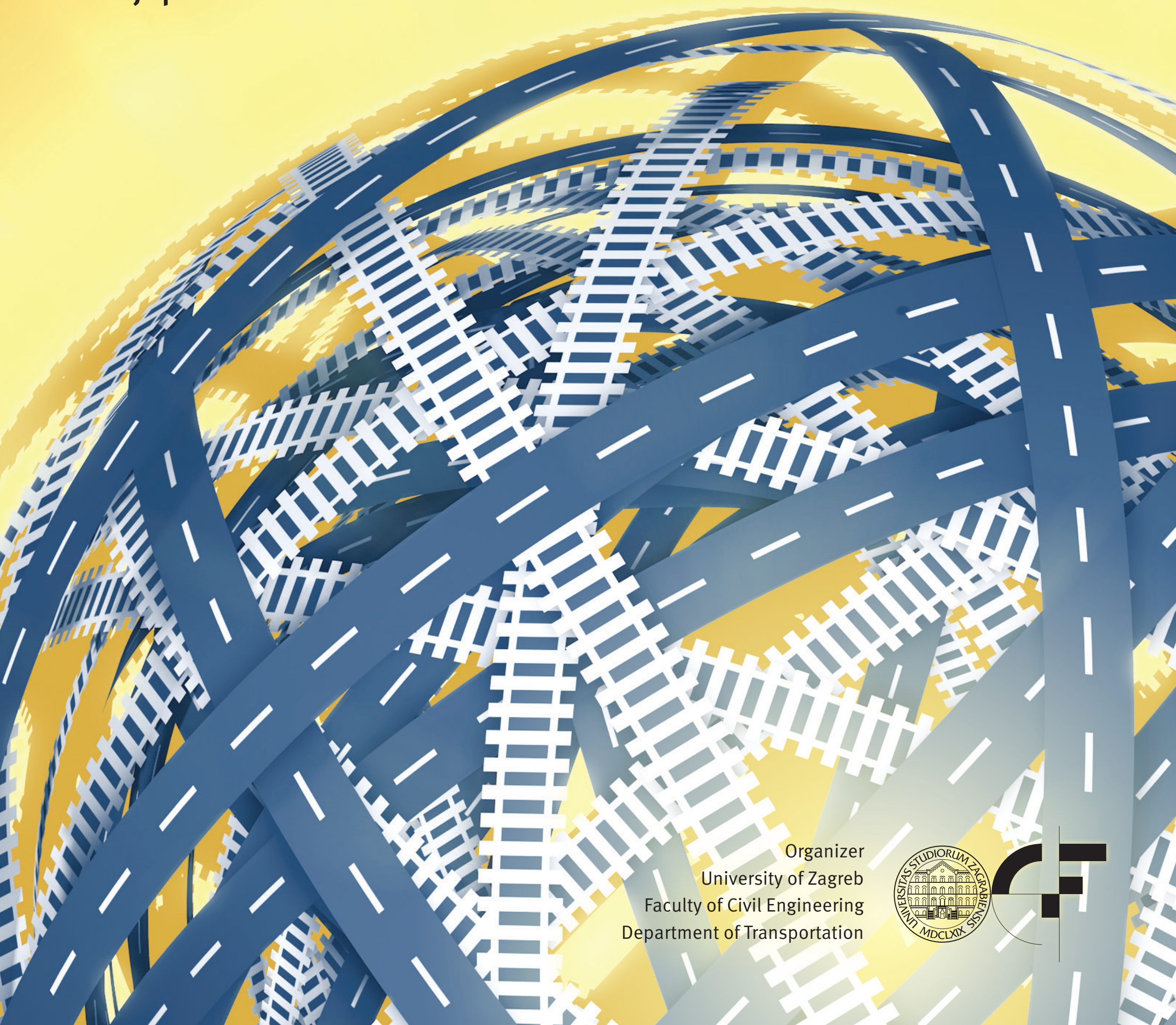
CETRA[2016]

4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

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POSSIBILITIES OF ENERGY SAVINGS IN HOT-MIX ASPHALT PRODUCTION

Zdravko Cimbola[1], Zlata Dolaček-Alduk[2], Sanja Dimter[2]
[1] COLAS Hrvatska d.d. Varaždin, Croatia
[2] University of Osijek, Faculty of Civil Engineering Osijek, Croatia

Abstract

The Energy development strategy of Republic of Croatia defines the efficient use of energy and maximum application of cost-effective measures, with the aim of reducing energy consumption. According Strategy, projections indicate that by the year of 2030 the world's energy consumption will increase by 50% compared to today's consumption, which implies the need for energy sustainability. Like other industries, the production of hot mix asphalt (HMA) in the asphalt plant requires a considerable amount of energy. HMA production involves significant consumption of thermal energy as well as an adverse effect on the environment.
Operating mode of existing asphalt plants in the Republic of Croatia involves substantial energy consumption for drying and warming of chippings in the rotary drum. Combustion of gas, fuel oil or other energy sources, mineral mixture is dried and heated to the required temperature. Increasing of moisture content into the mineral mixture can significant increase required temperature for drying and warming, and thus can increased consumption of energy. Analysis of current situation in the asphalt plants was found that segment of conversion and using energy still do not use technical and technological innovations in the field. Moisture of aggregates and lack of regulated and covered landfills conducted in the minimum inclination, for outflow of drainage water, the problem is almost all asphalt plants in Croatia. The paper analyses the contribution of mineral mixtures dehumidification in reducing energy consumption and the possibility of using exhaust gas energy in the production process of asphalt mixture.

Keywords: HMA production process, energy efficiency, utilizable energy potential, exhaust gas flow, moisture content of aggregates

1 Introduction

The Republic of Croatia, like other countries, is facing with the challenges arising from climate change, increasing energy consumption, costs and very strict environmental requirements for the preservation of the surrounding soil, air and water. The adoption of the document The Energy development strategy of Republic of Croatia in 2009, Croatia has undertaken for the efficient use of energy and maximum application of cost-effective energy efficiency measures, with the aim of reducing energy consumption. According to the Strategy [1], the industrial sector contribute to the total final energy consumption more than 20%, with a slight, but steady increase in energy consumption in recent years (Table 1).

Table 1 Energy consumption by all sectors [1]

sector	2006.	2015.	2020.	2030.
Industry	58.86	75.82	84.43	103.09
Transport	85.63	124.51	135.22	152.59
Other sectors	123.40	162.42	189.95	245.16
Total (PJ)	267.89	362.75	409.60	500.84

Analysis of current situation was found that segment of conversion and using energy (including construction industry) still don't use technical and technological innovations in the field. Current attention in the production of asphalt mixes in asphalt plants focuses on the asphalt production without thinking about possible improvements or cost savings in the production process. Asphalt production involves significant consumption of energy for drying and heating aggregate. Depending on mineral material moisture specific heat requirement per metric ton of asphalt mixed is between 70 kWh to 100 kWh [2]. These energy costs constitute significant percentage of the total cost of asphalt mixture production.

Table 2 Final energy consumption by industrial sector [3]

Sector	2009.	2010.	2011.	2012.	2013.	2014.
Iron and Steel Industry	2.34	2.67	2.56	1.65	2.06	2.12
Non-Ferrous Metals Industry	0.55	0.47	0.59	0.63	0.63	0.58
Non-Metallic Minerals Industry	2.37	2.42	2.38	2.15	2.15	2.13
Chemical Industry	9.20	8.55	7.92	5.34	5.33	5.54
Construction Materials Industry	**16.35**	**15.09**	**13.11**	**12.15**	**12.79**	**12.52**
Pulp and Paper Industry	2.77	3.04	2.77	2.68	1.74	1.63
Food Industry	9.46	9.95	9.67	9.11	8.56	8.58
Other Manufacturing Industries	8.10	8.11	7.96	7.86	7.68	7.53
Total INDUSTRY (PJ)	51.14	50.30	46.96	41.56	40.92	40.63

An increasing interest in assessment of energy consumption through production processes in different industry sectors shows potential in the field of reducing consumption using waste heat or exhaust gases to reduce load on fuel consumption, Table 2. This paper describes the analysis of the asphalt production process in asphalt plants, the current energy efficiency of asphalt plants and possibility of improvement.

2 Production of Hot Mix Asphalt (HMA)

2.1 General

Hot mix asphalt (HMA) is a composite material, whose major components are the aggregates (sand and coarse aggregates), the filler and the bitumen. Asphalt mixes can also contain different kinds of additives to improve the performance of mixes, such as adhesion agents, modifiers or fibers. The graded aggregates constitute almost 90% in mass of the mixes. The matrix consist of a mastic composed by bitumen, the filler and (sometimes) additives, where the bitumen is the 5% of the mixes and the filler the remaining 5%.
Currently, in the Republic of Croatia asphalt mix produces at about 56 asphalt plants [2]. Total monthly production possible with the existing capacity is about 1.6 million tons of asphalt mixes. Five asphalt plant capacities are greater than 200 t/h, fifteen plants are capacity of 150-200 t/h, and thirteen plants are capacity of 100 to 150 t/h, while the other plants are with

a capacity of 100 t/h (six less 50 t/h). During 2015, all Croatian asphalt plants produced a total of 2.15 million tons of asphalt mixtures for the construction and maintenance of roads [2]. Technological processes, performed on a discontinuous asphalt plant, can be carried out differently. Phase of asphalt production can be divided into the following operations: (1) pre-dosing of stone fractions; (2) drying and heating the mineral mixture; (3) dusting muddy dusty particles from the mineral mixture; (4) sifting hot mineral mixture; (5) weight or volumetric dosing fractions of mineral mixture; (6) dosing of bitumen; (7) mixing the heated mineral mixture with the binder; (8) storing of hot asphalt mix and transport (Figure 1).

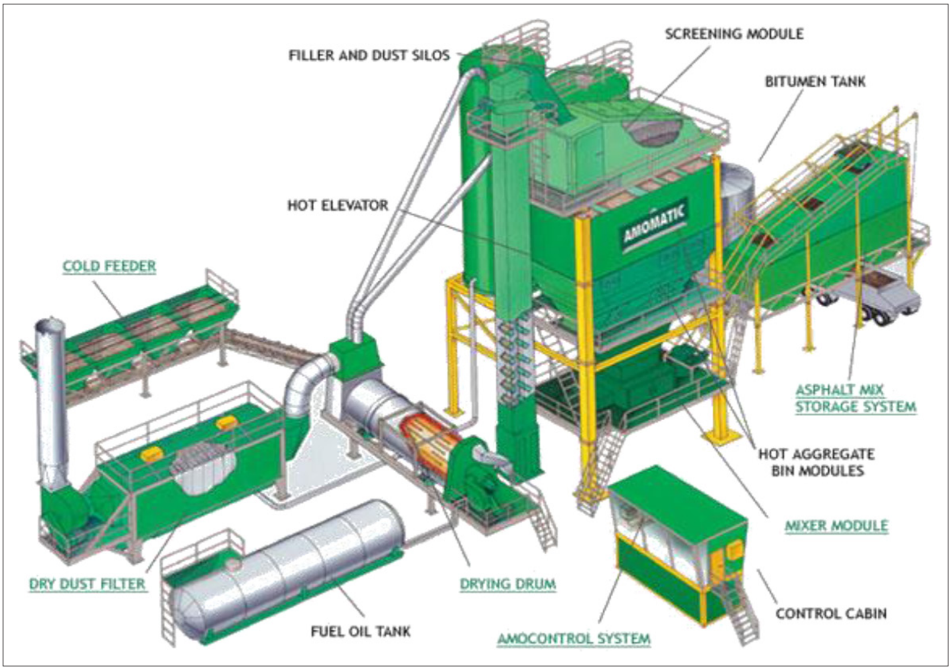

Figure 1 Production of HMA in the asphalt plant [4]

For pre-dosing fraction of chippings and sand pre-dosers are used: series of 4 to 5 containers with holes in the bottom with a mechanism for releasing the mineral material. Drying and warming mineral mixture is performed in a rotary drum dryer. The drum has a burner, which throws intense flames by almost the entire length of the drum. Rotating the drum, with the help of internal spiral blade, stone mixture rises and from the highest point discharges through the flames. Every particle of stone mixture passes several times through the flame so it can be thoroughly dried and warmed. De-dusting small, dusty particles of stone mixture is carried out in the dust collection unit, consisting of a strong fan and collector. Dried, de-dusted and heated mineral mixture from the rotary drum with elevator transmitted to the central part of the asphalt plant where is screened in two, three or more fractions. Then mineral mixture is weighed and discharged into the mixer. The unheated filler is added into the mixer and mixed with chippings about 5 seconds. Finally, into the mixer is added the heated bitumen and stir until it reaches wrapped of complete stone parts. Temperature of asphalt mixture depends on the temperatures of stone chips, bitumen and filler and can affect on the quality of produced asphalt mix or the possibility of its application. Asphalt mixture temperature must be, for these reasons, strictly controlled during the production process. After mixing, asphalt mix will be unloaded into the truck or stored in the storage silos for short time.

2.2 Critical spots in the HMA production

Current operation of existing asphalt plants in Croatia means insufficient utilization of production capacity and substantial consumption of energy caused by the volatile production of asphalt mixes and use of cold and wet stone fractions. At the time of increasingly stringent environmental requirements, as well as striving to realize significant savings of energy in industrial processes, with analysis of existing asphalt production can be notice more critical places. The critical places consume more energy than needed and produced energy is irretrievably lost:

1) Pre-dosers; dosered the cold and wet stone fractions – consumption of energy due to drying and heating is highly dependent on precipitation and ambient temperatures;
2) Rotary drum for drying and heating mineral aggregate; combustion of gas, fuel oil or other energy mineral mixture is dried and heated to the required temperature. Due to the use of mineral mixture with a higher moisture content leads to reduction of the material flow as well as the realization of lower working capacity of asphalt plants;
3) Containers for stored bitumen; due discontinuous work (the production of asphalt mixes), insufficient utilization of asphalt plants, consume large amounts of energy to maintain the operating temperature of stored bitumen (at certain times of bitumen is heated, without any production);
4) Chimney for exhaust gas; due to the work of asphalt plants in the ambient air is discharged significant amounts of heat energy. Exhaust gas flow contain significant energy potential.

3 Utilization of energy potential in the HMA production

Researches related to energy analysis during the asphalt production and opportunities for energy conservation and costs are in focus for many years. Ang et.al. [5] formulated thesis that the aggregate moisture is main factor influencing the level of energy consumption in the HMA production process. They measured the aggregate moisture located on the storage of two asphalt mixing plant and determinate the implied upper moisture limits of field aggregate. Authors also concluded the short atmospheric falls lead to an important increase of the aggregate moisture. They found that reduction in aggregate moisture of 3% reduces energy consumption in drying by 55-60%.
Research conducted by Jenny [6] shown with a reduced mixing temperature from 165°C to 115°C and reduced aggregate moisture content from 4% to 2% the energy savings are approx. 2.5 kg of fuel per ton of asphalt. Author also concluded the work process concept reduces the moisture content of aggregates to less than 2% and this reduction leads to energy saving of 1,5 kg of heating oil per ton of asphalt.

Table 3 Energy savings from reduced aggregate moisture [7]

% moisture before change	% moisture after change								
	1.0	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**	**5.0**
1.0	0%								
1.5	8%	0%							
2.0	15%	7%	0%						
2.5	21%	14%	7%	0%					
3.0	26%	19%	13%	6%	0%				
3.5	30%	24%	18%	12%	6%	0%			
4.0	34%	29%	23%	17%	11%	6%	0%		
4.5	38%	33%	27%	22%	16%	11%	5%	0%	
5.0	41%	36%	31%	26%	21%	15%	10%	5%	0%

National Asphalt Pavement Association (NAPA) [7] presented opportunities for energy conservation in the HMA production process addressing specific actions that represent the largest potential for energy savings. Reducing aggregate moisture content is possible to achieve by sloping, paving or covering the aggregates. Producers report energy savings up to 10% by insulating dryer shells or surfaces. Other proposed actions are reducing exit gas temperatures, reducing exit material temperatures, using alternative fuels, using more efficient hot-oil heater designs, employing more effective piping insulation, using more effective tank and silo insulation and using variable frequency drives in large motors. Possible energy savings from aggregate moisture content reduction are presented in Table 3.
Peinado et al. [8] analysed energy and exergy of a rotary dryer in HMA production in asphalt plant. The parametric study had shown great impact of HMA temperature and moisture on the energy requirements for producing of HMA, although the influence on the energetic efficiency was low.
Sivilevičius [9] concluded the required temperature of HMA production, thus energy consumption, depends not only on the moisture and on temperature of mineral materials, fuel quality but also depends on the structure of asphalt mixing plant.
Grabowski et al. [10], [11] analysed test and measurements results (in two time phases) of the energy consumption during HMA production. Results shown that reduction in overall aggregate moisture content of about 1% decreases the real oil consumption by about 18%. Also concluded the organizational changes in the work system of asphalt mixing plant may significantly influence the energy consumption in the HMA production without additional financial costs.
Androjić [4] analysed share of moisture in mineral mixture and energy consumption and concluded that increase in the temperature of a mineral mixture results in reduced natural gas consumption per ton of asphalt mixture produced. Based on boundary temperature curves the removal of 1% of moisture in mineral mixture resulted in 13.13% to 4.51% energy savings for material heating.
In general, based on previous research results potential that occurs due to the production of HMA in asphalt plants is visible. Especially because of large amounts of unused energy created by heating a mineral mixture, which is released into the atmosphere in the form of exhaust gases.

4 The energy potential of exhaust gas

Linking the cycles into asphalt mix production would be possible to achieve savings in energy consumption and reduce amount of exhaust gas. Using part of the thermal energy from exhaust gases for heating mineral materials on dumps, moisture content of aggregates fractions will be reduce and, thus, time required for their preheating will be shorter.
The idea is to remove part of the moisture from the composition of mineral mixture using exhaust gas in the drying process. As part of the preliminary research stone material on a conveyor belt was exposed to convection drying taking into account air temperature, air velocity, belt speed, material layer thickness and drying time. For the experimental part of the project a laboratory device was structured consisting of drive fan unit / drying chamber with hot air, a device for measuring the mass of samples and devices for measuring the temperature of the samples.
The speed of the conveyor belt allows exposure of the stone material to heat hot air for 30, 45 and 60 seconds. The temperature of the hot air was constant during each measurement simulate the conditions of heating hot air exhaust gas temperature by taking into account the thermal losses incurred by supplying exhaust gas to the conveyor belt. Measurements are provided for three air temperature achieved during experiment 33.1°C, 50.4°C and 71.7°C. First results show the energy potential of exhaust gas during the short-term drying process (Figure 2).

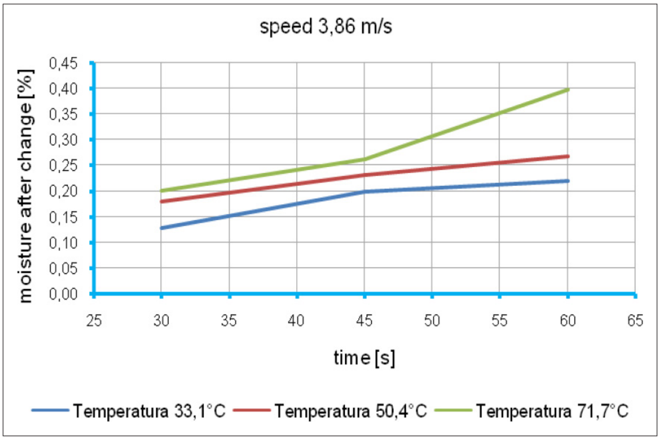

Figure 2 Preliminary results for aggregate moisture reduction

5 Conclusion

Production of construction material is energy demanding connected with present environmental issues. Hot-mix asphalt production is no exception. For many years, asphalt industry tries to find the balance between dynamic fuel market and possibilities to improve production process to reduce costs provided by technology development. The development progress relies on careful assessment of production process in order to find every possibility to contribute to the energy conservation. Many interventions have managed to rationalize energy consumption, but the today's challenge is to go further on developing the production process more environmentally friendly and energy acceptable. Proposed research and preliminary results are contribution to establish the model that describes the relationship of moisture content and temperature of mineral mixtures according to the temperature of hot air and the duration of short-term drying process. Proposed model could allow optimization of the technological process of production of asphalt mix and contribute to the implementation of technical innovations in hot-mix asphalt production.

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