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THE MODELLING OF EMISSIONS EVALUATION AT ASPHALT MIXING PLANT IN HOT RECYCLING

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Abstract. Transport industry with its infrastructure sector is one the main sources of GreenHouse Gas (GHG) emissions. In parallel, this industry has the main part on gross domestic product of a high transport transit countries with a develop road network. Transport infrastructure (TI) must be continuously developed, improved, and carefully maintained accordingly traffic and goods flow with respect to safety and emissions. Renewable resources, such as Reclaimed Asphalt Pavement (RAP) and energy from sustainable sources are the main accents reducing carbon emissions in the industry. The comparison outlook of different technologies emissions in a Hot-Mix Asphalt (HMA) with RAP production at Asphalt Mixing Plant (AMP) are presented in this paper. CO_2 emissions comparison of different RAP additions models and fuel types was analysed. The calculation model was presented for carbon emissions in most critical GHG generated AM production stage as new aggregates and RAP drying and heating.

Keywords: asphalt mixing plant, emissions, reclaimed asphalt pavement, burner, fuels, drying drum.

Notations

Abbreviations:

AM – asphalt mix;
AMP – asphalt mixing plant;
C – carbon;
CH_4 – methane;
CO – carbon monoxide;
CO_2 – carbon dioxide;
CO_2e – equivalent carbon dioxide emission;
HMA – hot-mix asphalt;
GHG – greenhouse gas;
NO_x – nitrogen oxide;
N_2O – nitrous oxide;
O_2 – oxygen;
RAP – reclaimed asphalt pavement;
RHMA – recycled hot-mix asphalt;
TI – transport infrastructure;
VM – virgin materials;
VOC – volatile organic compounds.

Variables and functions:

c_A – air heat capacity;
c_{GG} – combustion gas heat capacity;
c_F – fuel heat capacity;
c_{RAP} – RAP heat capacity;
c_V – vapour heat capacity;
c_{VM} – virgin material heat capacity;
ΔH – enthalpy;
ΔH_F – fuel enthalpy;
ΔH_V – water vapour enthalpy;
L_B – heat loses in burner;
L_R – heat loses in rotating drum;
m_A – all air in the drum mass flow;
m_{CA} – combustion air mass flow;
m_F – fuel mass flow;
m_{RAP} – RAP mass flow;
m_{VM} – virgin material mass flow;
Q_A – all air heat power;
Q_{CA} – combustion air heat power;
Q_{CG} – combustion gas heat power;
Q_F – fuel heat power;
Q_L – loses heat power;
Q_{RAPi} – RAP inlet heat power;
Q_{RAPo} – RAP outlet heat power;
Q_V – vapour heat power;
Q_{VMi} – virgin materials inlet heat power;
Q_{VMo} – virgin materials outlet heat power;
T_A – ambient air temperature;
T_{CA} – combustion air temperature;

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T_{CG} – combustion gas temperature;
T_F – fuel temperature;
T_i – inlet temperature;
T_{RAPi} – RAP inlet temperature;
T_{RAPo} – RAP outlet temperature;
T_V – water vapour temperature;
T_{VMi} – virgin material inlet temperature;
T_{VMo} – virgin material outlet temperature;
w – moisture.

Introduction

The pavement of road, as the element of a TI, is deforming, reduces its performance and finally is degrading on an influence of vehicles axle loads, climate, and weather conditions as well as vehicles and road maintenance consumables. It is necessary to recondition the pavement damages restoring their characteristics to conditions, which are suitable for vehicles traffic. In asphalt pavement the most fastest characteristics changes are of binder due to its irreversible aging processes. A pavement oxidation model was developed and investigated by Cui *et al.* (2018) using simulation tools. Asphalt pavement that is economically and technologically unsuitable for repair by removing local damage (breakage, potholes, cracks, ruts) is regenerated by recycling its material. The regeneration process brings not only benefits (Zaumanis *et al.* 2014), but also environmental damage due to the emissions of pollutants into the ambient air.

Currently one of the most important topics of developed countries is minimizing the GHG emissions (Peinado *et al.* 2011), which critically important criterion for environmental rating (Kim *et al.* 2012). The new stricter requirements have a profoundly serious impact onto development of many transport system processes including its infrastructure construction. The transport industry is the key source in 1/4 of GHG emissions (IEA 2021) in a high transport transit countries as Lithuania where 30.9% (LR AM 2021) total GHG emissions are generated in transport sector. The transport industry part of CO_2 emissions is near like Denmark where approximately 95% of the emissions directly caused by TI construction and operation (Schmidt, Dyre 2012). Large quantity of studies on the carbon emissions from the road transport industry and environmental impact have been published by scientists. Difficulties with production technology have been reported, including excessive emissions (Mogawer *et al.* 2012).

The old TI pavement must be dismantled and crushed to 32 mm and smaller RAP size for its recycling at AMP to adapt regenerations principles and technologies submitted in paper by Sivilevičius *et al.* (2017). The most common method of old pavement dismantling is using mobile asphalt cold milling machine with picks mounted on its rotating drum (Sivilevičius, Martišius 2021).

Sustainable economy states aim to increase the amount of RAP in RHMA, thus using almost all the RAP amount available in the country in the production of RHMA mixtures. The maximum possible added amount of RAP to RHMA depends on RAP homogeneity that is evaluated according to 5 characteristics (Vislavičius, Sivilevičius 2013). With decreasing of RAP homogeneity determined by variation of old bituminous binder content and its softening point, amount of a filler aggregate, fine aggregate, and coarse aggregate, decreases amount of allowed to add RAP into RHMA mixtures. Simulation method and algorithm (Sivilevičius, Vislavičius 2019) allowed to determine the maximum amount of RAP in RHMA mixture meeting the process technological limitations of its production and minimizing the cost of the mixture.

Itoya *et al.* (2012) revelated that AMs production, site operation, waste transportation, operative travel and asphalt delivery led to the greatest use of carbon. These processes were important aspects of sustainability decisions, which could help road designers, managers, and maintainers to prioritize a reduction in the above-mentioned types of emissions.

New emissions restrictions on toxic substances (Umweltbundesamt 2019) are forcing to search and implement new TI production of RHMA with RAP additions methods using alternative fuel sources. RAP recycling on hot mix batch plant is one of most cost and resources effective HMA, used for TI environmentally friendly pavement construction, production method (De Picado Santos *et al.* 2010). During conventional hot asphalt pavements production processes (Chollar *et al.* 1989) CO, NO_x, solid C particles, VOC and CO_2 notable quantities are emitted as high energy resources are needed (Butt *et al.* 2014).

Del Carmen Rubio *et al.* (2013) presents the results of a research study the main objective of which was to analyse environmental benefits derived from cleaner production technology for manufacturing AMs. Combustion gases (CO, NO_x, O_2, CO_2), total organic carbon, particles, VOC and polycyclic aromatic hydrocarbons were measured when manufacturing hot and half-warm asphalt in the plant, during laying and compaction process.

Main challenges are set on local natural aggregates as virgin mineral material supply optimising transport distances, use of RAP (Williams *et al.* 2020) and production methods to reduce emissions through energy savings. 3 main thermodynamics processes occur during the drying and heating of virgin mineral materials and RAP (Hossain *et al.* 2015):

- »» conduction;
- »» convection;
- »» radiation.

In a time of conduction process, virgin mineral materials are superheated (Martišius, Sivilevičius 2020) to transfer heat by direct contact between particles of virgin material and RAP respectively. The heat transfer by mean of convection and radiation to RAP is provided in a parallel drum with co-current material flow to minimize binder overheating and emissions with exhaust gas temperatures approx. 160 °C or in counter-current material flow with indirect material heating with exhaust gas temperatures approximatelly 100 °C. Solid materials heating in the co-current material flow were investigated by Le Guen *et al.* (2011) and Piton *et al.* (2013). This HMA production stage is the most significant emission source and here is a wide space to reduce the energy consumptions reducing a moisture of granular particles used for HMA production (Grabowski *et al.* 2013).

Most of GHG emissions research link to the complete asphalt pavement construction cycle. In this paper, the calculation model of global warming potential and the analysis on influencing factors of emissions were given based on the analysis on energy consumption during drying and heating of materials, new and recycled, process. This could be a theoretical background for the further research in low emissions technology for HMA production. The results indicate CO_2e emissions possible reduction by 4.3 and 29.3% adding RAP part to HMA by 30 to 45% with 2.1% lower moisture content. This paper will take review about hot RAP addition application operating 2 drying and heating drums (virgin and parallel) on AMP.

1. Drying and heating process in AMP

One of the main components on AMP is a mineral material (virgin aggregates) heating and drying drum (Figure 1). Cold mineral materials in the separate fractions are dosed from the feeding bins and transported by belt conveyors to the rotating drying and heating drum. The drum is equipped with a burner where required amount of heat is created due burning different gas, liquid, or powdered fuels. Heat and combustion gases flow through complete length of the drum transferring heat energy to materials. Material is fed in counter flow direction of a burner fire and transferred to heat source direction. Additionally, special lifters are installed inside the drum creating during the rotation so-called material curtain for material drying and heating.

1.1. Sustainable RAP application in hot recycling

Materials are heated for 2 main reasons:

- to evaporate residual water in material;
- to raise the temperature of materials starting from 110 °C to have enough heat quantity to mix asphalt at provided temperature, which is within 140 °C to 195 °C range.

During the production process of sustainable HMA with RAP addition, virgin materials are heated to the higher temperatures up to 250 °C and RAP up to 130 °C (Table 1). In order to add higher amounts (more than 40%) of RAP, another heating drum for RAP is installed. This drum is called parallel drum for 2 reasons. The drum is operating parallel to virgin material drum and RAP flow inside the drum is parallel to the heat direction. Operating both drums in parallel lower virgin materials heating temperature is required (Table 1).

The heat energy is produced by mean of burner. Historically fossil fuels such as natural gas, liquefied pressured gas, light oil, diesel fuel, sale oil, coal dust and others are used to create heat flow by burning them and produce enough heat quantity, which could be used for the virgin material or RAP heating and drying. AMP burners are generating high quantities of energy and develops from 4 to 40 MW, which could dry from 45 to 450 t/h of virgin materials or RAP if their moisture does not exceed 3% and heat materials up to the required by application type temperature (Table 1). In this stage, GHG emissions could be controlled by supplying and storing the materials in order to keep as lower as possible moisture amount and less fuel would be consumed just to evaporate the water. Next step is to change from fossil fuel to renewable fuel types such as wood dust, wood pallets or chips, methanol or similar, green hydrogen, biogases, biomasses and others.

Figure 1. AMP with heating drum (bottom center) and parallel drum on top

Table 1. Virgin and RAP material temperatures required for different RAP recycling in-plant methods (Martišius, Sivilevičius 2020)

Requirements RAP recycling in-plant	Method	Required virgin aggregate temperature [°C]	RAP temperature [°C]
Cold RAP addition (ambient temperature)	drum middle ring	160	ambient
	into hot elevator (hot bin bypass)	superheated up to 300	ambient
	into the mixer		
Hot RAP addition	parallel drum	superheated from 220 to 250	up to 130
	counter-flow with indirect heating	160	up to160
Combined RAP addition (cold/hot)	cold addition into the mixer + parallel drum	superheated from 220 to 300	ambient for cold, and from 110 to 130 for parallel drum

In hot and combined RAP recycling process, recycled material is heated from 110 to 130 °C. Residual moisture (water) is evaporating in this temperature range. After water is evaporated binder softening process begins. Main objective is to prevent binder overheating thus not decreasing its characteristics.

1.2. Drying and heating process model

Presuming that higher RAP content will lead to the lower emissions. Heat balance model founded on principles of energy and mass transfer balance between aggregates or RAP and hot gases. Schematically input and output heat powers provided on Figures 2 and 3.

In a case of heating virgin materials Figure 2 there are 4 inputs: Q_F, Q_{CA}, Q_A, Q_{VMi} and 4 outputs: Q_{CG}, Q_V, Q_L, Q_{VMo}. This balance is given in form of Equation (1):

$$\begin{Bmatrix} Q_F \\ Q_{CA} \\ Q_A \\ Q_{VMi} \end{Bmatrix} = \begin{Bmatrix} Q_{CG} \\ Q_V \\ Q_L \\ Q_{VMo} \end{Bmatrix}. \quad (1)$$

In case of RAP heating Figure 3 there are 4 inputs: Q_F, Q_{CA}, Q_A, Q_{RAPi} and 4 outputs: Q_{CG}, Q_V, Q_L, Q_{RAPo}. This balance is given in form of Equation (2):

$$\begin{Bmatrix} Q_F \\ Q_{CA} \\ Q_A \\ Q_{RAPi} \end{Bmatrix} = \begin{Bmatrix} Q_{CG} \\ Q_V \\ Q_L \\ Q_{RAPo} \end{Bmatrix}. \quad (2)$$

Each heat energy could be expressed in extended form and Equations (1) and (2) written in new forms respectively as Equations (3) and (4) and admit that:

$$c_{CA} = c_A;$$

$$T_F = T_{CA} = T_A = T_{VMi} = T_{RAPi} = T_i:$$

$$\begin{Bmatrix} m_F \cdot (\Delta H_F + c_F T_i) \\ m_{CA} \cdot c_A \cdot T_i \\ m_A \cdot c_A \cdot T_i \\ m_{VM} \cdot (1-w) \cdot c_{VM} \cdot T_i \end{Bmatrix} = \begin{Bmatrix} (m_F + m_{CA} + m_A) \cdot c_{CG} \cdot T_{CG} \\ m_{VM} \cdot w \cdot (\Delta H_V + c_V T_V) \\ (L_R + L_B) \cdot m_F \cdot \Delta H_F \\ m_{VM} \cdot (1-w) \cdot c_{VM} \cdot T_{VMo} \end{Bmatrix}; \quad (3)$$

$$\begin{Bmatrix} m_F \cdot (\Delta H_F + c_F \cdot T_i) \\ m_{CA} \cdot c_A \cdot T_i \\ m_A \cdot c_A \cdot T_i \\ m_{RAP} \cdot (1-w) \cdot c_{RAP} \cdot T_i \end{Bmatrix} = \begin{Bmatrix} (m_F + m_{CA} + m_A) \cdot c_{CG} \cdot T_{CG} \\ m_{RAP} \cdot w \cdot (\Delta H_V + c_V \cdot T_V) \\ (L_R + L_B) \cdot m_F \cdot \Delta H_F \\ m_{RAP} \cdot (1-w) \cdot c_{RAP} \cdot T_{RAPo} \end{Bmatrix}. \quad (4)$$

In both cases, the heat power is used to evaporate the water. Aggregates and RAP has their own moisture content. To meet the requirements to the normative documents (LAKD 2008) virgin aggregates for HMA are screened on the final stage of processing in wet screening applications where 1.25 to 2.00 m^3 water is required for 1 t of aggregate screening. During wet screening process 92 to 95% of technological water flows down to fine faction and rest is conveyed with coarse fractions into the stockpiles. Fine fractions are processed with mean of dewatering equipment (moisture content 12 to 16%) and then stockpiled. All fractions are left to dry in stockpile before delivery to AMP. RAP contains residual water from pavement porous as well as water from the milling operations. Water content in RAP could be reduced during RAP processing in impact crusher. During this application high quantity of energy is released and RAP dries out (Martišius 2020).

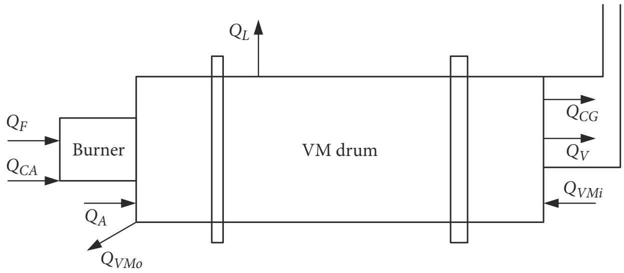

Figure 2. Heat balance model in the virgin mineral material counter flow drum

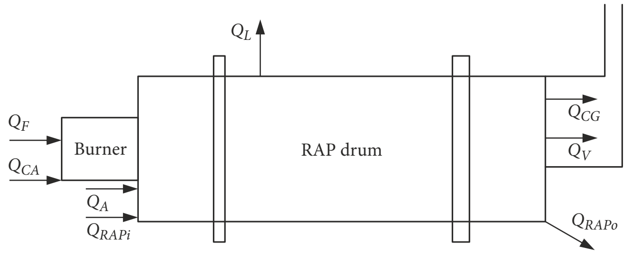

Figure 3. Heat balance model in the RAP parallel drum

2. Methodological and experimental research

The following assumptions and limits were considered in the calculation:

- optimized system with heat or energy loss Q_L through drum walls and burner respectively each of 3%;
- continuous combustion process (drums preheating and thermal system stabilization are not considered);
- 0% moisture content after drying.

2 RAP stockpiles with known properties were prepared. After laboratory test, it was found out that maximum used RAP quantity for addition to HMA is 63%. Due to AMP technical characteristics and HMA subbase AC16PD recipe evaluation, it was selected to add maximum 45% of RAP as well as HMA recipe with addition of 30 and 40% of RAP were created. As investigation aim is to compare fuel amount $\sum_{VM}^{RAP} m_F$ and energy consumptions

on AMP with different RAP moisture, part of RAP was stored under roofed area as another part of RAP in common field conditions. This would help to calculate possible CO_2e emissions with every scenario.

Ambient weather temperature was 17 °C, respectively to temperatures $T_F = T_{CA} = T_A = T_{VMi} = T_{RAPi} = T_i$ same number was applied. Finest fraction always contains highest percentage of moisture due to their biggest open surface area. Virgin mineral material moisture was presumed as finest fraction (sand 0/2 mm) moisture, which was measured to 5.1% and this assumed as total virgin materials moisture in this investigation. RAP moisture content from roofed and field areas respectively were 3.1 and 5.2%. Productions of approx. 230 t/h HMA with each recipe for 1 h were proceeded. Temperatures of heated virgin material T_{VMo}, heated RAP T_{RAPo}, exhaust gases T_{CG} respectively and HMA were monitored and fixed. AMP burner was running on natural gas with its enthalpy $\Delta H_G = 48000$ kJ/kg .

Having data of fuel consumption for each 3 scenarios of with different RAP ratio of 30, 40 and 45% addition to HMA, we are calculating theoretical CO_2e (UNFCCC 2021), which corresponds to global warming potential for each fossil fuel type. CO_2e is calculated considering that:

$$CO_2e = 1 \cdot CO_2 + 21 \cdot CH_4 + 310 \cdot N_2O. \quad (5)$$

3 groups gas, liquid and powdered types of fuels are used to create heat in AMP drying and heating drums (Table 2).

As example of the natural gas emissions are calculated as follows. Enthalpy for each fuel type, or energy units, are known and converted to mass emissions factors multiplying by energy basis for each of CO_2, CH_4 and N_2O gases:

$$48000 \cdot 0.000053 = 2.56 \text{ kg/t } CO_2;$$

$$48000 \cdot 0.000005 = 0.24 \text{ kg/t } CH_4;$$

$$48000 \cdot 0.0000001 = 0.0048 \text{ kg/t } N_2O.$$

Emissions are converted to CO_2e emissions and summed:

$$1 \cdot 2.56 \text{ kg/t } CO_2 + 21 \cdot 0.24 \text{ kg/t } CH_4 +$$
$$310 \cdot 0.0048 \text{ kg/t } N_2O = 9.088 \text{ kg/t } CO_2.$$

Table 2 contains additional data for each fuel such as enthalpy, CO_2, CH_4, N_2O, and CO_2e mass emission factors (EPA 2020).

We can derive required different fuel type mass for each burner m_F out of Equations (3) and (4) for theoretical calculations. Comparing to experimental research results same AMP output was selected and calculated required fuel mass per 1 ton AM after CO_2e emissions were calculated.

In many countries, each AMP owner or operator is obliged to pay so-called CO_2 taxes for each exhausted ton into atmosphere. Average tax rate in Europe is approx. 40 €/t CO_2 (end of 2020, Figure 4 (VšĮ ŽE)) and is calculated for used fossil fuels.

In 1990, Finland became the first country, which had applied such taxes, as Germany, is ready to start in 2021. Taxes are different in each country and differences are partly influenced by local energy resources. Poland has the lowest emissions taxes and nearly 90% of AMP have burners equipped for coal dust combustion. Estonia uses local shale oil as the fuel for the aggregates drying and heating in AM production. On the other hand, the highest CO_2 taxes are in some Scandinavian countries. There are several pilot test AMP in Scandinavian countries with integrated wood dust and wood pellets burners in operation. Other European countries are working on green hydrogen projects and this type of fuel is one of the most suitable to substitute natural gas in the AMPs.

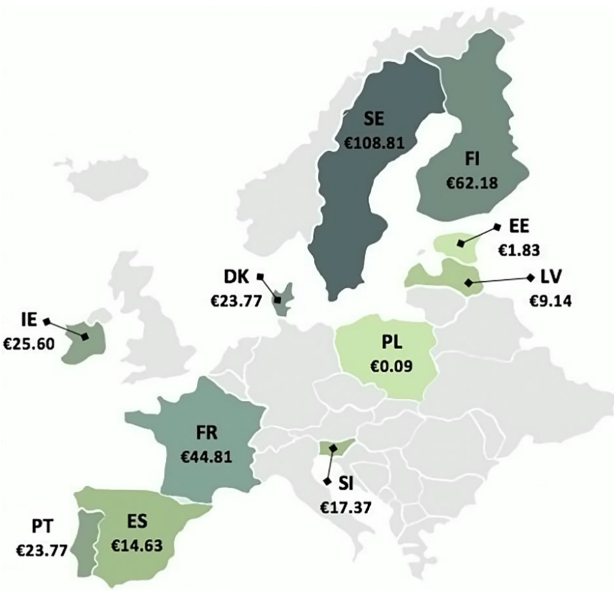

Figure 4. Map of CO_2 taxes (VšĮ ŽE 2021)

Table 2. Fuels for AMP

Fuel type	Fuel name	Enthalpy ΔH [kJ/kg]	CO_2 mass emission factor [kg/t]	CH_4 mass emission factor [kg/t]	N_2O mass emission factor [kg/t]	CO_2e mass emission factor [kg/t]
Gas	natural gas	48000	2.56	0.24	0.0048	9.088
	liquefied petroleum gas	47300	2.84	0.24	0.0047	9.273
Liquid	oil	40400	3.17	0.404	0.0242	19.17
	diesel	43000	3.15	0.43	0.0258	20.18
	shale oil	38100	2.79	0.38	0.0229	17.89
Powder	coal dust	11900	2.64	0.12	0.0178	10.69

In the period of experiment AMP, exhaust gas composition was measured with analysis box for exhaust gas analysis systems *Testo* 350. Data collected for CO, NO_x and SO_2 emissions. Average CO emissions were 381.5 mg/Nm^3, as NO_x – 58.2 and SO_2 – 0.00 mg/Nm^3.

3. Results and discussion

After calculations, theoretical results of theoretical CO_2e t per 1 t of HMA mixture in drying and heating process with adding RAP with moisture content of 3.1 and 5.2% are provided in Figure 5. In production of HMA with higher moisture content of RAP emissions are constantly increasing and with RAP containing lower portion of water markedly decreasing. CO_2e emissions reductions possible then RAP moisture content is lower that virgin mineral materials and RAP relative quantity in HMA is higher. With presumption that aggregates moisture is lower than RAP, CO_2e emissions are growing with higher RAP relative quantity in HMA. It is clearly noticeable that sustainable usage high quantities RAP with higher that virgin aggregates moisture is not possible. Higher moisture content leads to higher fuel consumptions and higher emissions on AMP.

Experimental data provides that real fuel consumption (Table 3) is higher than theoretical and fuel consumptions are higher that it was predicted before experiments. Possible reason of this effect is that trial was started with highest RAP moisture and quantity where the most strength of combustion was needed, and the highest amount of energy power consumed.

CO_2e emissions were calculated according to experiment in-plant data and results are provided in Figure 6. Emissions during HMA mixture production of higher RAP moisture content of 5.2% are tremendously increasing comparing emissions in production of HMA with RAP with 3.1% moisture content. Thus, comparing the theoretical results with experimental ones is clearly seen that emissions increases faster adding RAP with higher moisture content.

Once again, it was proved that storing RAP material in roofed areas fuel consumption is reduced by 4.3 to 29.8%. RAP roofed area construction investments in average are 30000 € and it would easily paid-off adding 50% of RAP to AM in production process dependently of used fuel type, its availability and price on the market. At the other hand less CO_2e emissions are released into the atmosphere.

Experimental data analysis provides clear view that theoretical calculation for expected fuel consumption and GHG emissions in RAP heating and drying process respectively are only valid with lower material moisture of 3.1% (material stored under the roofed area). Heating and drying RAP with higher moisture amount of 5.2% fuel consumptions with GHG emissions are increasing rather more than it was predicted in theoretical calculations and even higher if bigger RAP amounts of 40 to 45% are added.

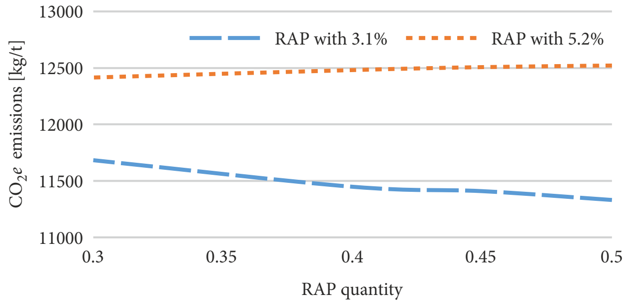

Figure 5. Theoretical CO_2e emissions with different RAP moisture and quantities

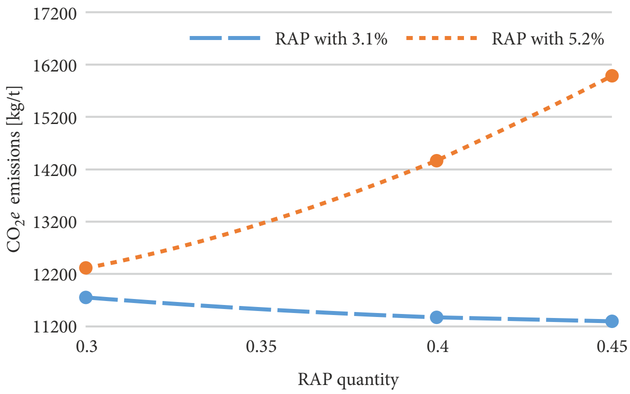

Figure 6. CO_2e emissions with different RAP moisture and quantities calculated from experimental data

Table 3. Natural gas consumption [m^3] for RAP recycling depending on RAP moisture %

RAP quantity [%]	Natural gas consumption [m^3] with RAP moisture content of	
	3.1%	5.2%
30	1294	1352
40	1248	1584
45	1243	1770

After the research of technical parameters for different burners and heating drums used in AMPs, it was stated that different burners and drums manufacturers provides their technical data respectively heating drum and plant production capacity with calculated input material moisture from 3 to 4%. This complies to the experimental results.

The trials should be performed as uniformly as possible under different weather conditions to determine dependence of fuel consumption and moisture content. Assuming that during spring and autumn seasons when the air humidity is more than 95%, fine grains to 5 mm of RAP as well as fine virgin materials fractions could intake moisture this effect would less significant. The ambient conditions also influence in account of lower initial materials temperatures and drying and heating drums optimal thermal regime achievement.

Conclusions

GHG emissions during HMA life cycle possible significantly reduce saving the energy needs in most fuel consuming stage in AMP. Thus, economic, environmental, and social added value would be achieved using RAP with lower moisture content stored in roofed areas.

It was stated the AMP manufacturers are on the safe side providing plant technical and output parameters with indication of lower input material moisture. As experimental data reflects higher fuel consumption and GHG emissions heating materials with higher moisture portions, manufactures recommendation keeping appropriate materials moisture should be more deeper scrutinized by AMs production companies.

Significant economical and industrial effects could be achieved producing sustainable HMA with maximum possible RAP content and lower moisture content. This would reduce fossil fuel and bitumen consumption, saving natural quarry resources, which all together leads to lower transportation costs and emissions.

Social effect would be achieved as less GHG would be emitted. Circular economy requirements demand on using renewable fuels in HMA mixture production.

Future renewable fuel types as wood dust or chips, biomass, bioethanol or biodiesel are started to use in AMPs. Renewable future fuels are selected as renewable energy from sustainable sources as biomass. Solar energy is accumulated in as wood, straw, or organic waste. Gas, liquid or solid fuels can be obtained from this kind of biomass. Other kind of fuels as alternative fuels such as hydrogen, pyrolysis gas and oil and others are not as discussion subject in this paper. Electricity as energy source was not considered in this paper as there is a lack in capacities of green electrical energy with huge power demand of 11 to 20 MW in AMP technically still is under trial phase.

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