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MULTI-ATTRIBUTE ASSESSMENT OF THE ASPHALT MIXING PLANTS

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ABSTRACT

Multi-attribute methods in road construction can be used on the national, organization and project levels. However, most of assessment methods are seeking to find how to make the most economic construction decisions, and most of all these decisions are intended only for economic objectives. Computerised Asphalt Mixing Plants (AMP) are one of the most expensive and complicated equipments for construction of road pavements. Modern AMP is controlling by computer program, but there still are some problems. Properties of the AMP not always satisfy demands and requirements of road constructors. Quality of the asphalt hot mixtures, environmental contamination, pollution, firm economic wellbeing and possibility to satisfy demands of the hot asphalt mixture users depends on the AMP quality. This paper proposes a multi-attribute model for efficient quality assessment of the AMP. For this problem were selected 9 main quality attributes and weighted by expert ranking method. The problem is solved by applying additive assessment. The case study is presented also.

KEYWORDS

Asphalt mixing plant, quality, attribute, assessment, additive

1. INTRODUCTION

Hot mix asphalt (HMA) are used for roads and motorways pavement laying. They are producing in central or mobile asphalt mixing plants. These technological equipment are named asphalt mixing plant (AMP). They are of three types: Batch plant, Drum mix plant and Continuous mixing plants. Construction of is is adopted for certain production technolgy of HMA. Technological process of HMA contains preparing (initial proportioning of cold aggregates, drying and heating, hot mix aggregate screening to 3 or 4 hot fractions, hot fractions, imported filler, required dust and asphalt cemment ptoportioning by weight) and main operations (hot mixing of averall prepared materials). It is necessary to distinguish between the HMA quality and the HMA production qulaity. The quality of HMA production is characterised by % of its mass meeting the job mix formula or normative documentation quality (componential composition, tempereture etc) requirements [9]. The quality of produced HMA depends as on quality of applied materialas and as on manufacturing quality. High of HMA making quality can be reached by automatisation of processess and computerised properly controlling them. But te main role plays operator. He must properly use pssibilities supplied by modern techmologies (Sivilevicius, 2005).

The modernisation history and evolution of AMP constructions are investigated and presented in many works [1-3]. The HMA producing technology and appropriate construction of AMP is in continous modernisation process. The aim of modernisation is seeking for the best HMA quality, productivity, reliability, technological universality, for less pollution of environment etc.

A lot of HMA quality quarantee problems produced in AMP of different construction and and automatisation processess according to many aspects were analysed and investigated. These problems are presented in Sivilevicius and Bunkin works [4, 6, 7, 10]. Robers et al [8] presented history of hot mix asphalt composition design methods. The modern and using in practice mtethods are presented by Asphalt Institute [14]. Sivilevičius and Vislavičius [5] presented study of the evaluation of the random errors influence of the stochastic technological process occurring in a batch type plant on the homogeneity of the hot-mix asphalt. They presents the algorithm of prognosing mineral part composition of HMA, which takes into consideration a variation of mineral material cumulative percent passing through control sieves as well as errors of mineral material dose weight in the finite dosing.

Dosing of materials is one of the most important part of the HMA producing process. The quality of HMA making rising as systematical and random proportioning errors decreasing. The making quality rises when segregation of hot aggregate fractions is diminishing [4, 6, 11].

HMA is producing by batches applying classical technology as in Lithuania as in most European countries. Quality of HMA produced by batch type AMP is assessing by applying proposed statistical methodology of control and operating [8].

AMP must satisfy all set of required properties. It must produce mixture of appropriate componental composition, temperature and homogenity, without pollution of environment, be able produce different groups and marks of mixtures. The produced mixtures mus not be expensive and etc (Sivilevičius, 2002). AMP quality can be evaluated by applying multicriteria additive complex model. The AMP model is describing by 9 discret criteria. Number of criteria can be changed. In civile engineering practice for muticriteria problems solutions can be applied different methods: game theory. TOPSIS, COPRAS, VIKOR, AHP, ELECTRE, ORESTE, ... [12, 13].

2. AMP MULTI-ATTRIBUTE QUALITY ASSESSMENT

AMP is very complicated modern and expensive technological equipment (Fig 1). The main operations are controlling by installed computer programs. These programs enable to AMP operators achieve high quality of HMA. For this reason operator must enter minimal tolerances of materials weights, temperature of materials and select required mixing time. When operator is working in regime of minimal tolerances the time of materials proportioning is very long that reduces productivity of AMP. Operators not always are setting minimal tolerances of material weight and this cause decrease of HMA quality. From this point of view HMA computerised operating only allows to achieve high quality only in case when operator enter proper operating regime. Operator can select and set different regime of AMP work: narrow-ranging, medium-ranging or wide-ranging tolerance of mass dozes. The quality of produced HMA in AMP is subjective and mostly depends on operators qualification and conscience. It depends also on controlling programs and personal.

3. CRITERIA OF AMP COMPLEX QUALITY ASSESSMENT

A multi-criteria mathematical model was developed to assess technological equipment quality. At first after investigation and expert questioning was determined set of the most significant AMP quality criteria. The additive assessment AMP quality function is as follows:

$$K = \sum_{v=1}^{h} R_v x_v = Cx_1 + Tx_2 + Hx_3 + Ex_4 + Px_5 + \\ + Wx_6 + Rx_7 + Bx_8 + Ux_9 \quad (1)$$

here $R_v - v$ criterion average range numerical value; h – a number of criteria in the model; x_v – variable depending on AMP v criterion factual and standard or limit parameters; *C, T, H, E, P, W, R, B* and *U* are loose terms showing the importance of HMA composition (C), temperature (T), homogeneity (H), production costs (P), HMA environmental protection (E), AMP physical and moral wear (W), repair and reconstruction costs (R), capabilities (B) and technological universality (U) criteria; $x_1, \ldots, x_9$ – variable arguments $(v = 1, \ldots, 9)$ making up the model, which are used when evaluating parameters $(x_v = 0,\ldots,1)$ influencing the value of each criterion.

The significance index was identified the calculation formula of mathematical model (2) arguments x_v was extended through experimental research of the data from the survey of 43 competent respondents according to a nine-point system enabled to write the

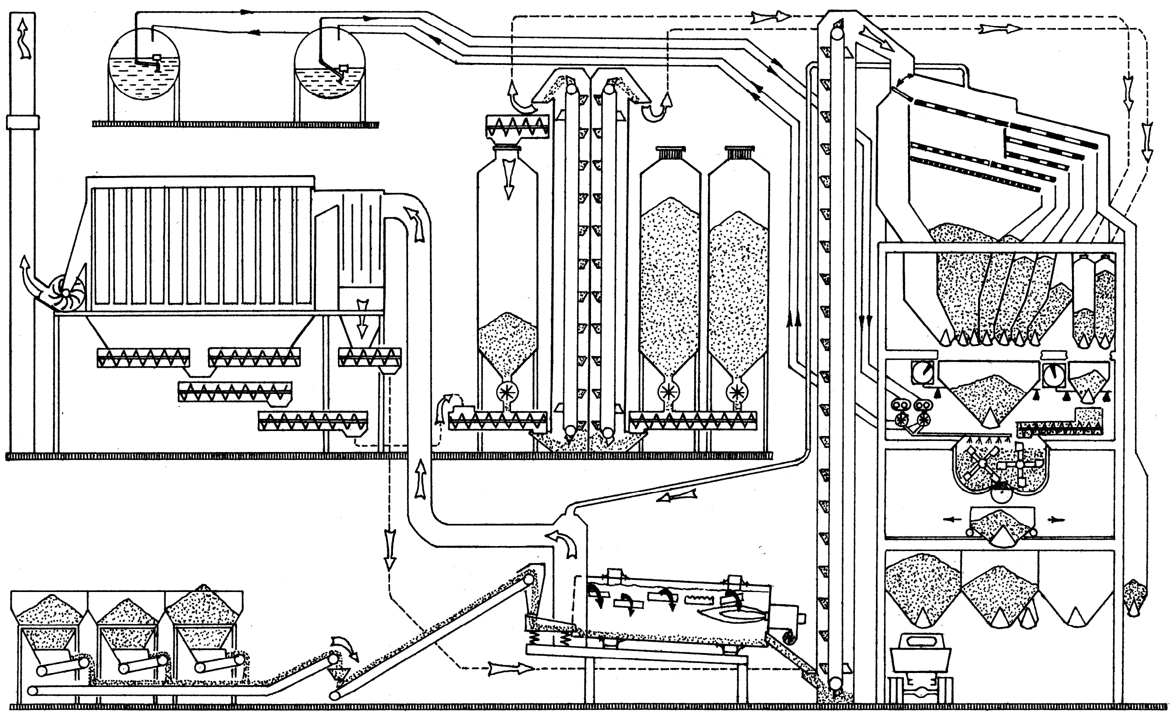

Figure 1. Construction of batch type asphalt mixing plant (AMP) and flow of materials in AMP

final AMP quality complex multi-criteria index K expression (Sivilevičius, 2002):

$$K = 0.1911\left[1-\frac{\sum_{i=1}^{k}\frac{|\Delta k_{fi}|}{|\Delta k_{ni}|}}{k}\right]+0.1622\left[1-\frac{|\Delta T_f|}{\Delta T_n}\right]+$$
$$+0.1685\left[1-\frac{\sum_{i=1}^{k}\frac{\Delta\sigma_{fi}}{\sigma_{fik}}}{k}\right]+0.1100\left[1-\frac{\sum_{j=1}^{m}\frac{c_j}{HPC_j}}{m}\right]+$$
$$+0.0869\left[\frac{b(s_{\max}-s_f)}{s_{\max}}\right]+0.0771\left[1-\frac{a_f}{100}\right]+$$
$$0.0542\frac{r_f}{r_{\max}}+0.0487\frac{p_f}{p_{\max}}+$$
$$+0.1013\cdot[A_{hma}++V_{hma}+SM_{hma}+V_{n\,hma}+V_{gr\,hma}+PA_{ca}+$$
$$R_{hma}+L_{hma}+W_{ma}+C_{ma}\ ] \quad (2)$$

here $|\Delta k_{fi}|$ – modulus of factual quantity mean $\bar{k}_{fi}$ deviation of i component contained in HMA (coarse aggregate – CA, fine aggregate -FA, fillers – F or bitumen - B) from job mix formula k_{pi} of this component, mass % $|\Delta k_{fi}| = |\bar{k}_{fi} - k_{pi}|$; $|\Delta k_{ni}|$ – value of i component quantity regulated deviation modulus, mass %; k – component quantity in the produced HMA (usually 4, sometimes 3); $|\Delta T_f|$ – modulus of HMA factual temperature mean $\bar{T}_f$ deviation from temperature's upper T_u and lower T_l values (tolerances) mean $0{,}5(T_u + T_l)$ set in the norms, 0C; ΔT_n– HMA regulated temperature tolerance depending on the brand of the used bitumen, $\Delta T_n = T_u - T_l$, 0C; $\Delta\sigma_{fi}$ – difference between the produced i component quantity standard deviation σ_{30i} in HMA mixture, obtained when mixing in HMA mixing plant for 30s, and this component's quantity standard deviation σ_{fik}, indicating constructional capacities of a mixing plant to reach maximum HMA homogeneity according to i component, when mixing the mixture for a rather long time $(\Delta\sigma_{fi} = \sigma_{30i} - \sigma_{fik})$, mass %; c_j – factual concentration of j pollutant emitted from AMP equipment to environment, mg/m3; HPC_j – highest permitted concentration of j pollutant mg/m3; m – a number of pollutant according to which AMP quality is identified; b – coefficient depending on the considered as the best set ratio between the lowest s_{min} and the highest (considered as the worst) s_{max} net prices; s_f – factual net price of HMA in the investigated AMP, €/t; a_f – (total) value of AMP factual wear and tear, %; r_f – monetary costs allocated for AMP repair and reconstruction, €; r_{max} – highest expenses allocated for AMP repair and reconstruction, necessary to adjust it properly to carry out all functions, €; p_f – factual exploitation of AMP capacities during the working season (usually 8 months) to produce HMA of all types and brands, t/season; p_{max} – the largest possible quantity of HMA to be produced during the working season in AMP working at nominal work regime, t/season; $A_{hma}, V_{hma}, SM_{hma}, V_{n\,hma}, V_{gr\,hma}, PA_{ca}, R_{hma}, L_{hma}, W_{ma}, C_{ma}$ – shows a possibility to produce HMA of relevant brands in AMP, evaluating each of them 0,1.

Factual values of evaluated AMP arguments $x_1,...,x_9$ calculated from the data HMA laboratory investigations, production accounting documents, pollutant emissions and financial reports. The value of the best (ideal) AMP multi–criteria complex quality index K is 1, average: 0.5, and the worst: 0.

Values of evaluated AMP arguments $x_1,...,x_9$ are calculated from the data HMA laboratory investigations, production accounting documents, pollutant emissions and financial reports. The value of the best (ideal) AMP multi–criteria complex quality index K is 1, average: 0.5, and the worst: 0.

4. KEY STUDY

The proposed assessment of AMP quality methodology was applied in practice. 4 AMP were selected for assessment. The criteria values were calculated according to AMP technical characteristics. These means are presented in table 1. According to initial calculated values we state that some of criteria are better in one alternative while some others are better in another one. It is unclear what the best AMP is. The ranking and assessment of alternatives is setting by applying proposed methodology. The ranking and assessment results are presented in table 2 and figure 2. The results show that the best alternative is 4. We can state that 4th alternative is better than 1st one, the 1st alternative is better than 3rd alternative and finally 3rd alternative is better than 2nd one. The alternatives ranks as follows: $4 \succ 1 \succ 3 \succ 2$.

Table 1. Decision-making matrix for quality assessment of AMP

Variant	Criteria under consideration								
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9
1	0.69	0.75	0.61	0.66	0.64	0.90	0.73	0.85	0.80
2	0.72	0.69	0.69	0.61	0.58	0.88	0.67	0.91	0.60
3	0.61	0.79	0.57	0.72	0.68	0.71	0.82	0.79	0.90
4	0.67	0.84	0.67	0.58	0.72	0.98	0.75	0.76	0.70
Optimum	*max*	*max*	*max*	*max*	*max*	*max*	*max*	*max*	*max*
Significance	C=0.191	T=0.162	H=0.168	P=0.110	E=0.087	W=0.077	R=0.055	B=0.049	U=0.101

Table 2. Results of AMP quality assessment

Variant	Criteria under consideration									Result
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	
1	0.13179	0.1215	0.10248	0.0726	0.05568	0.0693	0.04015	0.04165	0.0808	0.71595
2	0.13752	0.11178	0.11592	0.0671	0.05046	0.06776	0.03685	0.04459	0.0606	0.69258
3	0.11651	0.12798	0.09576	0.0792	0.05916	0.05467	0.0451	0.03871	0.0909	0.70799
4	0.12797	0.13608	0.11256	0.0638	0.06264	0.07546	0.04125	0.03724	0.0707	0.7277
Significance	0.13179	0.1215	0.10248	0.0726	0.05568	0.0693	0.04015	0.04165	0.0808	

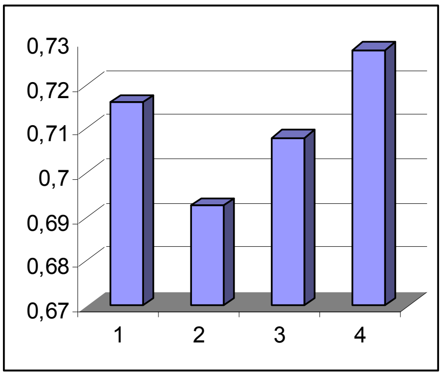

Figure 2. Comparison of complex quality evaluation of AMP under investigation

5. CONCLUSIONS

In this research work is proposed methodology for assessing quality of AMP. The model and selected assessment criteria set are presented also. This model allows compare and evaluates state and condition of AMP. The practical example shows that model is appropriate for practical use.

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