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PROGRESSIVE METHODOLOGY FOR DETERMINATION OF CONCRETE PLANTS PRODUCTIVITY

Abstract

The mathematical model for estimation of building machines productivity can have various forms of processing. When choosing the appropriate one, it becomes the qualitative tool for making optimal decisions. In this article, a nomogram for graphical determination of a concrete plant operational productivity is presented. It illustrates methods of its formation and instruction for the usage.

Keywords: concrete plant, productivity, nomogram

1. Introduction

Pertinent information related to theoretical productivity of machines is presented by their producers. It should be calculated by the mathematical formula. However, conscious and unconscious mistakes and the biased information (related to marketing of the products) may appear at some point. Thus, the information about the theoretical productivity of the machines may be – at some point – somewhat misleading. More complex situation emerges, when it comes to the estimation of the building machines real productivity. That can be significantly lower than their estimated theoretical productivity. Unfortunately, the producers generally tend not to reveal that kind of information. Therefore it is significant, especially for building and designing companies, to complete and verify the missing information. This is often a very difficult task [1].

The aim of this research was to propose the form of data processing regarding productivity of building machines. This is helpful, since it delivers quick and relatively correct technique. Thus one may obtain information about technical productivity and simultaneously be able to estimate operational productivity (under specified conditions) during the building process. The results of this investigation led to design of the nomogram. This nomogram may be used for estimation of technical and operational productivity of concrete plants. In order to compose a particular model, detailed analysis of technical and technological parameters of concrete plants was necessary. This information is required by machines' building companies and used as the input data. Many factors having significant impact on operational productivity were also considered in this analysis.

2. Mathematical modelling of building machines productivity

Mathematical modelling of the productivity in the process of building machines and machines assemblies is one of the significant tools. It enables to make the optimal decisions regarding projects of machines assemblies and schedules in building processes [3].

Generally one may state that: 'building companies do not want the formulas!'.

This does not necessarily implies, that building companies reject mathematical modelling. They only deny working with models.

Mathematical formulas are needed for preparation of building processes and composition of machines line-ups. They are also required for static calculations and project's documentation. They posses many disadvantages too, e.g.:

– ignorance or lack of a suitable mathematical formula,
– incorrect measure units in substitution of some parameters,
– mistakes regarding exact value,
– mistakes referring ‘mathematical symbol’,
– the necessity of a calculator or a computer (calculation without aid is ineffective),
– the amount of ‘valid numbers’ in the final value depends on the calculator and does not present an exact value for obtained information,
– the analysis of model sensitivity in relation to changes of entered parameters is expressed only via mathematical aid and is often invisible,
– the practical interpretation of numerically expressed data, which is obtained by calculation is missing.

The methods of data processing regarding the following model are important for building companies.

The mathematical model can be expressed in various ways, e.g. in tabular or graphical form (not only via mathematical way). These methods provide information about the values of sensitivity analysis considering parameters changes of entered information. Furthermore, this model enables a backward look at analysis of sensitivity values. When applying this model it is possible to decide which parameter values should be entered when using the pre-determined values of productivity.

The mathematical model of operational productivity of concrete plants and a new, progressive form of its processing allows to eliminate the disadvantages of the mathematical formulas. It became the qualitative tool for making optimal decisions in various technological processes. For example: during the projects of machines assembly for production, transportation and treating of fresh concrete.

3. Productivity of concrete plants

The real and operational productivity are still lower than their theoretical productivity. The reason for that is that theoretical productivity refers to both fresh concrete and ideal operational conditions.

3.1. Real productivity of concrete plants

The operational productivity of concrete plants is still lower than its estimated technical (theoretical) productivity [2]. Real productivity of concrete plants is calculated by multiplying the technical productivity by correction variables.

$$V_S = V_T \prod_{i=1}^{n} k_i$$

where:
V_S – operational productivity of a concrete plant, $m^3 \cdot h^{-1}$;
V_T – theoretical productivity of a concrete plant, $m^3 \cdot h^{-1}$;
k_i – i-th correction variable;
n – number of correction variables.

The operational productivity of a concrete plant depends on its technical productivity and following variables:
– variable of working productivity of a concrete mixer ($\boldsymbol{k_{pú}}$) – presents standard conditions of a manufacture process,
– variable of concrete mixer filling ($\boldsymbol{k_{pm}}$) – presents measures for net (useful) capacity of a concrete mixer,
– variable of operational time of a concrete plant ($\boldsymbol{k_{ho}}$),
– variable ($\boldsymbol{k_{tm}}$) – presents the extension of the fresh concrete mixing time, which is necessary in case of adding some ingredients and mixtures to concrete.

Operational productivity of machines, is derived from their technical productivity multiplied by ($\boldsymbol{k_{pú}}$), which is the working productivity variable. This variable varies from 0.7 to 0.85 in standard conditions of a concrete plant.

The under-used full capacity of a concrete mixer decreases its productivity during the mixing of concrete components. On the other hand, overflow a concrete mixer can affect its incomplete mixing. Eventually, the devastation of fresh concrete or damages in some parts of the mixer may occure as a consquence.

The concrete production depends directly on its sales. Fresh concrete is ready to use as soon as the process of mixing begins. Therefore, it is not possible to produce fresh concrete ‘in stock’. Batches of fresh concrete mixture, which are placed under the mixer, are able to partially counterbalance the unsteadiness of concrete. Therefore, it is only possible to serve continuous filling for transportation. But it is difficult to store fresh concrete temporarily. The variable of unsteadiness time of concrete required from the concrete plant ($\boldsymbol{k_{ho}}$) varies from 1.4 to 2.2. For example, the variable k_{no} = 2 means, that during the 8-hour shift, it has been required for concrete to flow only 4 hours. For the next 4 hours, the concrete mixer should have a downtime. In this case, concrete plants produce and supply just a half of concrete capacity compared to its operational productivity. We can also estimate an average time of concrete production per shift during the calculation of concrete plants operational productivity.

Next aspect that has a significant impact on production is the addition of a different ingredient(s) into concrete. Interaction between some ingredients is activated by mixing. Therefore the producers recommend extending the time of mixing in a concrete mixer from 30 to 120 seconds. That time depends on a type of the mixer and the technical facilities. The mixing time consists of its filling, mixing and discharge. For example, extension of the mixing time from 30 to 120 seconds, prolongs then the previous mixing time of a concrete mixer from 60 to 150 seconds. As a result, mixing centre productivity changes at only 40% ($\boldsymbol{k_{tm}}$ = 0.4) as compared to the previous production.

The real conditions of concrete production (alongside with an impact of those factors that have a significant impact on concrete plant real productivity), are necessary to be considered in order to plan the process of concrete production.

For building companies, it is desirable to determine operational productivity of concrete plants in particular condition. The reason is that the outage and supplies of fresh concrete during the ***planning and management of building construction*** concrete process may cause serious problems or delays in the schedule. Therefore, the nomogram is the suitable tool for making optimal decisions.

4. Nomogram for determination of concrete plants operational productivity

The procedure of determination of concrete plant productivity includes five stages [4]. The presented sequence is illustrated in a **graphical version of a mathematical model** as the nomogram.

1. The net capacity of a concrete mixer is the basic information needed for the calculation. Also, the recommended concrete volume per one batch (2/3 of net capacity of a concrete mixer) is presented. In case when one batch possesses capacity lower than recommended, the following step should be estimated, considering lower concrete volume. The graphical model presents concrete volume per one batch in m^3. Typical sizes of concrete mixers that are used are: 150, 375, 500, 750, 1000, 1125, 1500, 2000, 2500 and 3000 litres.
2. The time of each mixing cycle (filling, mixing, and discharge of a concrete mixer) has a significant impact on theoretical productivity of a concrete mixer. Smaller mixers have a minimal time of 60s per each cycle and 70s for bigger one. In fact, concrete plants usually work with longer production cycle. Certainly, the needed mixing time can be extended due to a longer mixing time. This is required when some additional mixtures are added into fresh concrete. The cycle time varies from 60 to 300s in the graphical model.
3. The operational productivity of a concrete mixer is calculated by multiplying technical productivity of a concrete mixer by variable of working productivity (k_{pu}). The value of working productivity variable varies from 0.6 to 0.85. This is presented from 0.1 to 1.0 in the graphical model below.
4. The operational productivity of a concrete mixer is usually not the same as the operational productivity of a concrete plant. In fact, concrete is not available for production ‘in stock’. The number of hours necessary for concrete production during one shift can be significantly lower than the length of the shift. In the graph, the dependency function is presented as 0, 1, 2, ..., 7 and 8 hours of concrete production during one shift.
5. The final value represents an average operational productivity of a concrete plant in $m^3 \cdot h^{-1}$ and operational productivity of a concrete plant per one shift.

It is possible to estimate technical productivity of a mixer from the nomogram. It depends on the net capacity of a concrete mixer (or volume of concrete mixture in one batch) and a particular time of a concrete mixer working cycle (compound from filling time, mixing time and discharge time of a concrete mixer). It is possible to estimate operational productivity of a concrete mixer, following the expected value of variables of working productivity. Considering an expected time of concrete production per one shift it is also possible to establish real productivity of a concrete plant and average time.

The procedure regarding estimation of concrete plant technical and real productivity is presented in nomogram (Fig. 1). It can be seen that when the time of mixing extends from 30s to 120s (some concrete admixtures demand the minimum 2 min of mixing time) the accurate mixing cycle time appears to be 150s. Moreover, during the relatively high value variable and amount of hours of concrete production per one shift, the final productivity of a concrete plant does not reach the third of its value, which derives from the technical productivity of a concrete plant. That is taken from guidebooks.

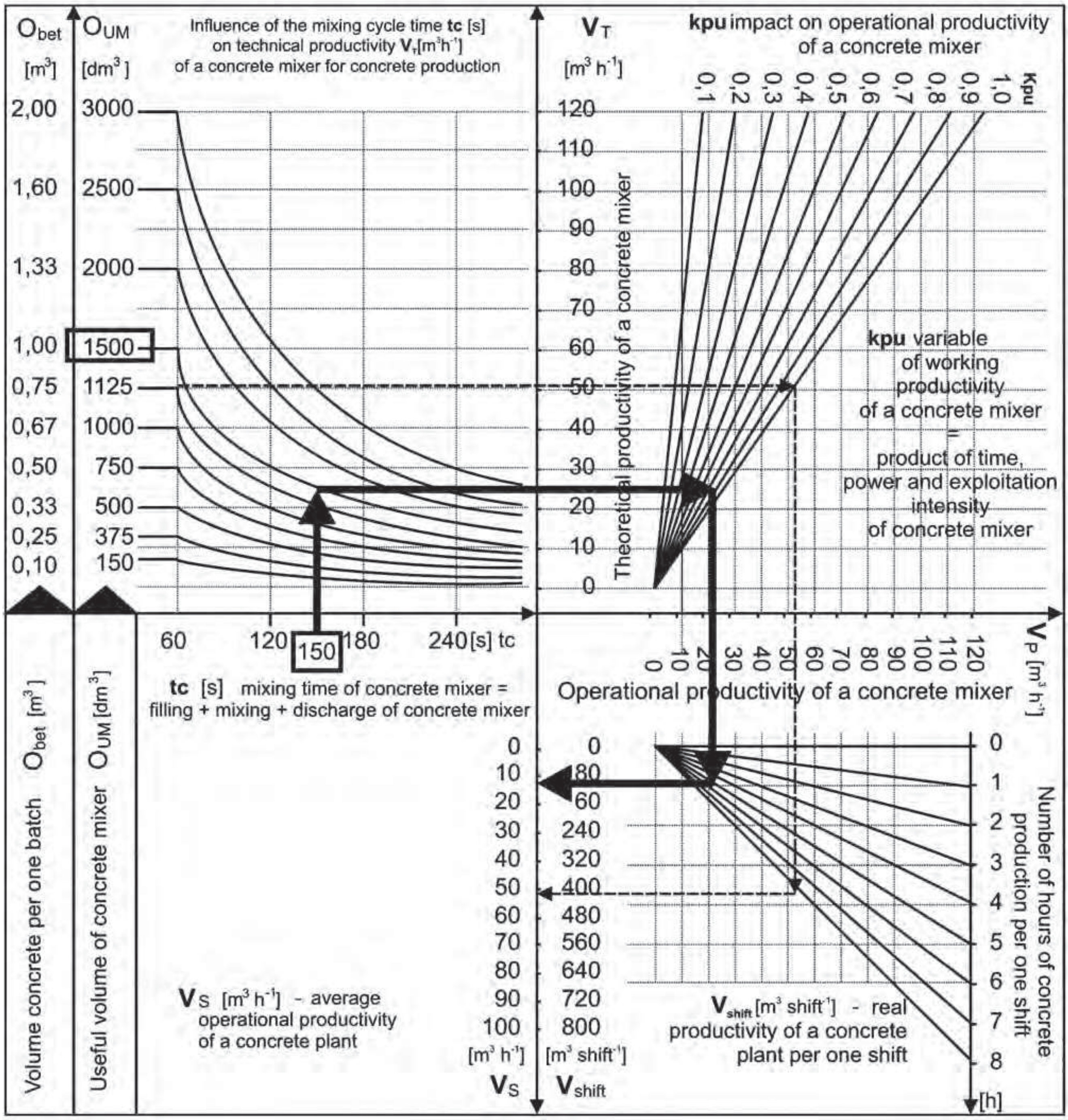

Fig. 1. The nomogram for estimation of operational productivity of a concrete plant

It is possible to use this nomogram “backwards” – ‘with backward procedure of obtaining values’. For instance, we can establish what kind of a concrete mixer is necessary for required daily concrete plant productivity. This information is significant when designing the production facilities (i.e. before the plant is built).

Considering mathematical modelling, correct and precise information is very important. The measure of information accuracy (input or output), which is processed in the model above, have to be known in advance. It is also necessary to take into account the usage purpose of this model.

In the presented nomogram, the correctness measure of obtained information for lower capacity of concrete mixers is relatively low. However, in this case, it is acceptable to obtain approximate values (in case when we need the exact value, it would be possible to estimate particular values using a calculator and following simple calculation procedures from the nomogram. Values from the graph can be used as a "guard" of correctness for the values substitution in particular units). At last, the nomogram provides clear information about crucial factors and their significant impact on operational productivity of a concrete plant. That fact can accelerate and improve the decision process when objective information is needed.

5. Conclusions

It is possible to eliminate the risk during the process of realisation by correct estimation of operational productivity of machine assemblies. Accuracy and precision in provided information about concrete plants are one of the problems that many building companies encounter during the concrete process and realization of monolithic constructions. New material and new technologies often pose higher demands when it comes to the quality of fresh concrete mixture. They might have the negative impact on the mixing time. Nevertheless, this is just one of the many factors that have a significant impact on operational productivity of a concrete plant. There are many other factors that have to be taken into consideration such as unsteadiness, requirements for concrete during the working shift, etc.

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Deterministyczna metodologia określania wydajności betonowni

1. Wprowadzenie

Celem niniejszych badań jest propozycja sposobu określania wydajności maszyn budowlanych, co w rezultacie pozwoli na szybkie i relatywnie bardzo dokładne uzyskanie informacji nie tylko o wydajności technicznej, ale i głównie oszacowanie wartości wydajności eksploatacyjnej maszyn w poszczególnych warunkach produkcji budowlanej. Jednym z wyników badań częściowych przedłożonego projektu jest nomogram dla określenia technicznej i eksploatacyjnej wydajności betonowni.

Matematyczne modelowanie wydajności maszyn budowlanych i montażowych stanowi jedno ze znaczących narzędzi ułatwiających podejmowanie optymalnych decyzji podczas projektowania maszyn budowlanych i planu realizacji procesu budowlanego.

Układ modelu matematycznego wydajności eksploatacyjnej dla betonowni i nowy progresywny sposób sterowania nim, eliminujący wady stosowania wzorów matematycznych, może stać się jakościowym narzędziem dla procesu podejmowania optymalnych decyzji podczas projektowania maszyn do produkcji i transportu świeżej mieszanki betonowej.

2. Zakres i metodyka badań

Procedura obliczania wydajności betonowni została podzielona na pięć etapów. Przedstawiona sekwencja została również przedłożona w wersji graficznej modelu matematycznego do formy nomogramu.

1. Podstawowa wielkość, która jest niezbędna dla kompletnych obliczeń, to objętość użyteczna betoniarki. Zalecana objętość betonu dla jednej porcji wynosi 2/3 objętości użytecznej betoniarki. W przypadku gdy jedna porcja jest mniejsza niż zalecana objętość, kolejny etap jest liczony z prezentowaną niższą objętością betonu. Objętość betonu na jedną porcję w m^3 jest przedstawiona w modelu graficznym. Użyte są typowe rozmiary betoniarek: 150, 375, 500, 750, 1000, 1125, 1500, 2000, 2500 i 3000 litrów.

2. Czas cyklu mieszania (napełnianie, mieszanie, opróżnianie betoniarki) ma znaczący wpływ na wydajność techniczną betoniarki. Mniejsze betoniarki betonowni posiadają minimalny czas jednego cyklu 60 s, większe betoniarki 70 s. Jednakże, betonownie zwykle pracują z dłuższym czasem cyklu mieszania. Potrzebny czas mieszania może być wydłużony poprzez wymagany dłuższy czas mieszania przy użyciu niektórych domieszek do świeżej mieszanki. Czas cyklu waha się od 60 do 300 s dla tego modelu graficznego.
3. Wydajność eksploatacyjna betoniarki jest obliczana przez pomnożenie wydajności technicznej betoniarki przez zmienną wydajności (k_{pu}). Wartość zmiennej wydajności waha się od 0,6 do 0,85. Na modelu graficznym wartość $k_{pú}$ jest przedstawiona od 0,1 do 1,0.
4. Wydajność eksploatacyjna betoniarki nie musi się równać wydajności eksploatacyjnej betonowni. Mieszanka betonowa cyklicznie produkowana jest w betonowni i fakt, że nie może być ona składowana „na zapas” oznacza, że ilość roboczogodzin produkcji mieszanki podczas jednej zmiany może być znacząco niższa niż długość zmiany roboczej. Na wykresie, zależność jest przedstawiona przez funkcję dla 0, 1, 2, ..., 7 i 8 godzin produkcji mieszanki betonowej podczas jednej zmiany.
5. Powstała w procesie wartość jest średnią wydajnością eksploatacyjną betonowni w $m^3 \cdot h^{-1}$ i wydajnością eksploatacyjną betonowni przypadającą na jedną zmianę.

3. Podsumowanie

Eliminacja ryzyka w procesach realizacji jest możliwa dzięki poprawnemu oszacowaniu wydajności eksploatacyjnej maszyn budowlanych i przez rozważenie ich w planie procesu budowlanego. Konieczność uzyskiwania danych o wydajności betonowni jest jednym z problemów, które firmy budowlane napotykają podczas planowania betonowania i realizacji konstrukcji monolitycznych. Użycie nowych materiałów i nowych technologii do produkcji i pielęgnacji świeżej mieszanki betonowej stawia często wysokie wymagania w stosunku do jakości mieszanki betonowej, co może mieć zły wpływ na potrzebny czas mieszania w betoniarce. To tylko jeden z czynników, które mają znaczący wpływ na wydajność eksploatacyjną betonowni.