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RESEARCH REPORT NO. 3

The aplication of experimental and numerical methods. Obtained results

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The aplication of experimental and numerical methods. Obtained results

1. The measurement and and determination of cumulative parameters

The experimental method application consists in the measurement and and determination of cumulative parameters for a number of automated stations and their tabular and graphic representation with the purpose to highlight:
- the variation mode of the mixing time with the consistency or the mode to obtain the target consistency at the same mixing time value when moving from one concrete class to another;
- the respecting mode of the manufacturers recommandations, relating to the mixing time and/or cycle duration of concrete preparation;
- the cycle duration variation mode at concrete stations, with direct impact on the station productivity as well as operation reliability;
- the values of components dosing errors, fitted in the limits from CP 012/1-2007, that is $\pm 3\%$ for agreggates, cement and water and $\pm 5\%$ for additives;
- the obtained values of water/cement report, with maximum variation of $\pm 0{,}02$ in relation to the value prescribed in the laboratory recipe;
- the values of mixing rotation speeds, where it was possible their determination, taking into account that a variation of them bigger than ± 5%, being able to the reduction of fresh concrete workability and consistency.

2. Concrete compressive strength determination

The last cumulative parameter of concrete (of concrete station) is the concrete compressive strength.
The experimental results obtained for the compressive strength at 28 days for different mixing durations in various concrete stations, equipped with different mixers having different mixing systems (one vertical axis, two vertical axis or two horizontal axis) are used **for validation of relations between mixing time and the compressive strength**.
These relations validation is made through numerical method and experimental-numerical combined method, to see how much the proposed relations can be applied in practice, leading to adequate results obtained for the compressive strength.

For concrete with resistance class C 8/10 up to C 50/60, the compressive strength average values determined on cubes it would be recommended to respect relation (1):

$f_{cm}= f_{ck}+ 6\ldots12$ Mpa (1)

Therefore is recommended for these concretes that the compressive strength values determined on cubes to respect the values from the table 1.

Tabel 1

Concrete resistance class	Minimum resistance at 28 days(Mpa) on cubes	The domain in which should be the average resistance(Mpa)
C 8/10	10	16...22
C 12/15	15	21…27
C 16/20	20	26…32
C 18/22,5	22,5	28,5…34,5
C 20/25	25	31…37
C 25/30	30	36…42
C 28/35	35	41…47
C 30/37	37	43…49
C 32/40	40	46…52
C 35/45	45	51…57
C 40/50	50	56…62
C 45/55	55	61…67
C 50/60	60	66…72

The values from table 1 column 2 represent the minimum values which should obtained on concrete batches preparation, for respective classes and the target recommended values are in the middle of the domain shown in column 3.

In order to achieve this, the recipe must be followed exactly, the dosing errors and the water/cement report should respect the prescribed deviations and the mixing durations from the recipes and those actually performed to respect the recommended values by the mixer manufacturer, for types of prepared concretes.

3. Comparative study of cumulative parameters determined on a group of concrete stations with different productivities and various manufacture years

- *Graphical representation of effective mixing durations and those prescribed in laboratory recipes during the concrete preparation, for some concrete stations analyzed;*

Conclusions about the compliance of mixing durations prescriobed in the recipe and about the variation mode of effective mixing time with concrete class.

- *Graphical reprezentation of preparation cycle duration in relation with the value from technical data manual, for some analyzed stations.*

Conclusions about the concrete stations reliability, starting from the cycle duration increase, as a result of operation blockings, caused by a long term use.

- *Graphical representation of dosing errors for aggregates, cement , water, and additives in relation with the values prescribed in CP 012/1-2007*

Conclusions about the respecting mode of the values prescribed in CP 012/1-2007 and about the weighing precision of dosing systems.

Conclusions about the respecting water/cement report effective achieved during concrete preparation, taking into account by the maximum deviation of 0.02 in relation with the values from laboratory recipe.

- *Tabular reprezentation of analyzed stations functioning productivities in relation with those prescribed in the technical data manual.*

Conclusions about concrete stations functioning productivities, taking into account by the term use.

- *Tabular reprezentation of the rotation speeds values for mixers which endow the analyzed stations.*

Conclusions about the determined variations in relations with the values from prospectus.

In table 2, it was represented **for ten concrete stations,** reprezentative from point of view concerning to mixing- dosing- parameters processing systems, the values for the next cumulative parameters :

- mixing time from recipe and effective achieved;
- standard cycle duration and effective cycle duration;
- dosing errors during concrete preparation.

It was determined functioning productivities of concrete stations during concrete preparation, to compare with technical productivities values.

In table 3 are presented the mixers rotation speeds, being in the endowment of the ten concrete stations , (values from technical data manuals and values determined at no load regime).

Table 2

Nr. crt	$t_{m\,ret}$ (sec)	t_{cn} (sec)	t_{mef} (sec)	t_c (sec)	P_{th} (m^3/h)	P_{oper} (m^3/h)	Dosing errors according to CP 012/1-2007	Effective dosing errors (%)
1	30	84	33.4	98	96	82.6	Agreggates, water, cement± 3; aditives ±5	Agreggates 0.4; cement 0,2; water 0.25; aditives 1.24
2	30	60	36	72	60	50	Agreggates, water, cement± 3; aditives ±5	Agreggates 1.2; cement 0.66; water 0.78; aditives 1.12
3	30	60	30.2	74	60	48.6	Agreggates, water, cement± 3; aditives ±5	Agreggates 1.07; cement 0.33; water 1.16; aditives 2.14
4	30	67.5	31	78.3	80	69	Agreggates, water, cement± 3; aditives ±5	Agreggates 0.96; cement 0.24; water 0.38; aditives 0.76
5	40	90	42	109	80	66	Agreggates, water, cement± 3; aditives ±5	Agreggates 1.33; cement 0,58; water 0.79; aditives 1.36
6	40	135	41	146.5	40	36.8	Agreggates, water, cement± 3; aditives ±5	Agreggates 0.94; cement 0.77; water 0.35; aditives 1.23
7	45	82.6	50.3	88	98	82	Agreggates, water, cement± 3; aditives ±5	Agreggates 1.18; cement 0.42; water 0.59; aditives 1.49
8	45	85	49.4	94	106	95.7	Agreggates, water, cement± 3; aditives ±5	Agreggates 0.64 cement 0.18; water 0.26; aditives 1.94
9	45	108	46	122	50	36.9	Agreggates, water, cement± 3; aditives ±5	Agreggates 2.02; cement 0.98; water 0.52; aditives 1.56
10	45	120	45.4	126	45	35.7	Agreggates, water, cement± 3; aditives ±5	Agreggates 1.55; cement 0.36; water 1.32; aditives 2.66

Fig. 1

t (sec)

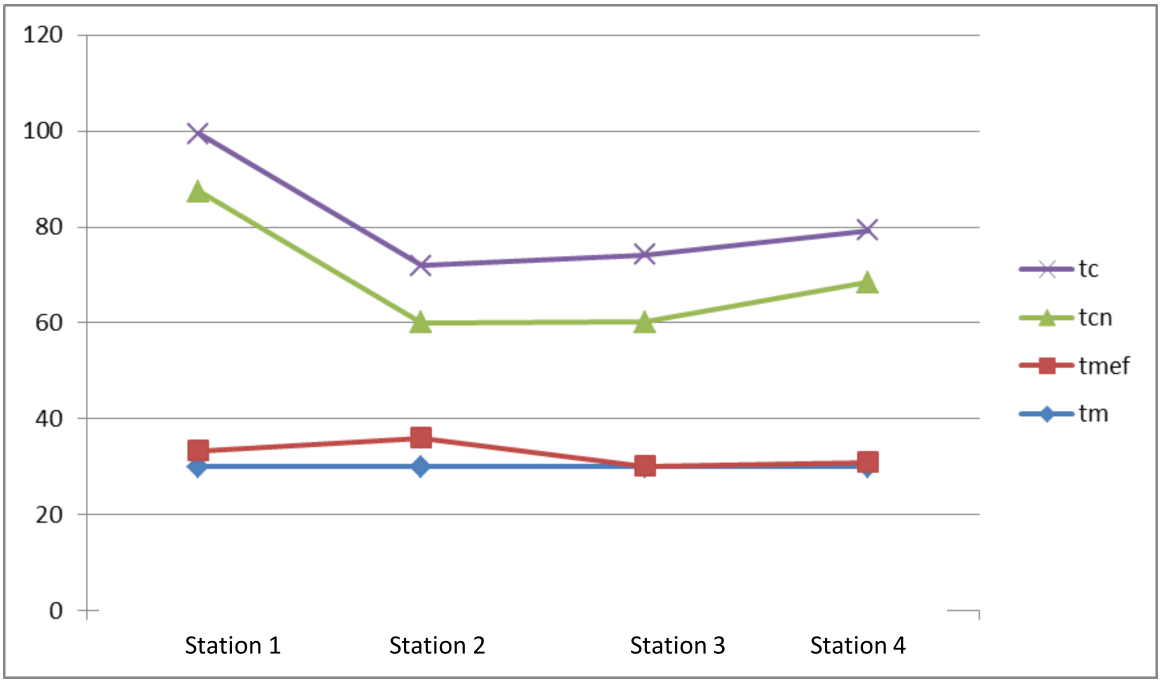


Fig.2

t (sec)

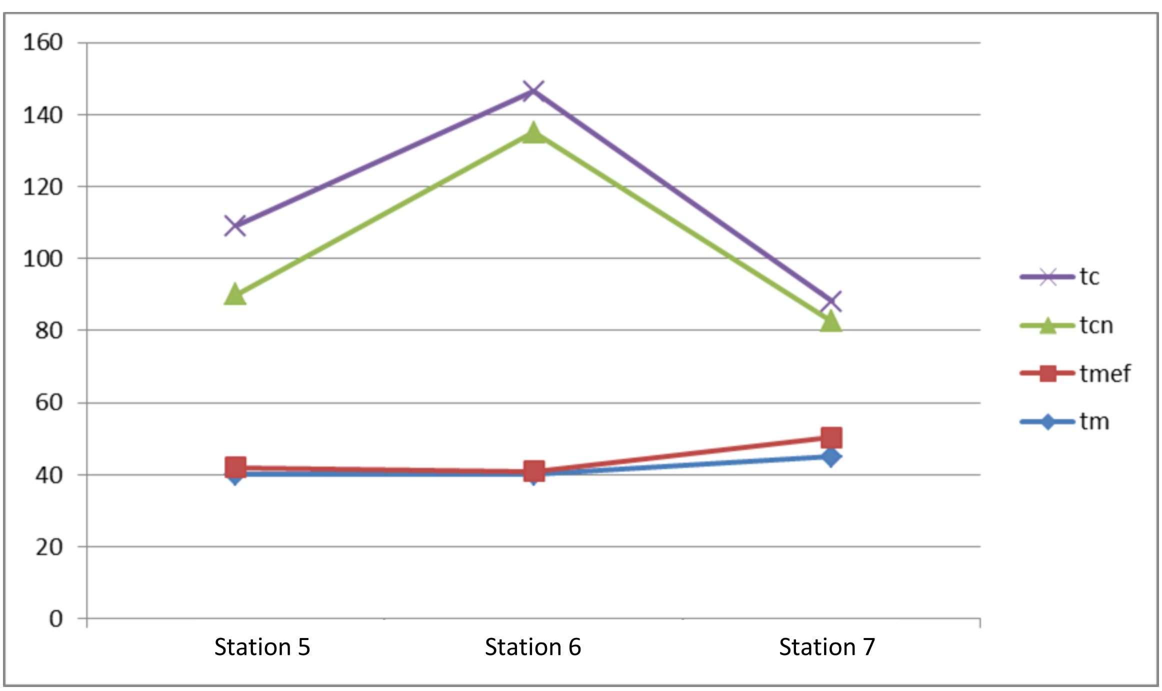


Fig.3

t(sec)

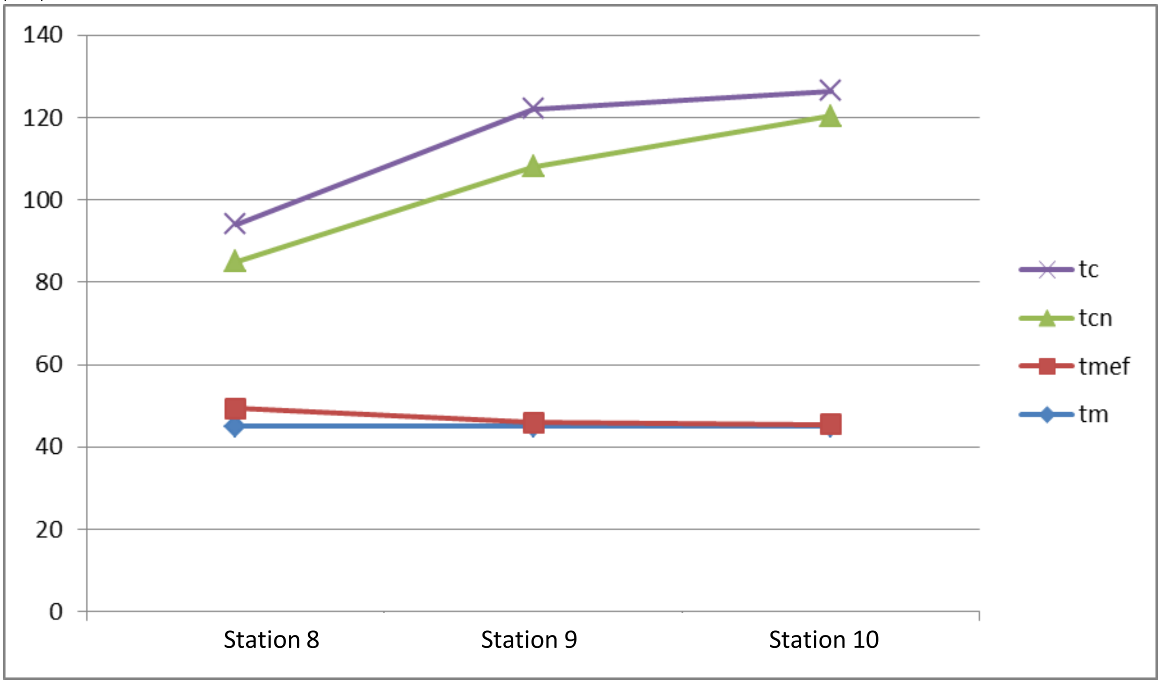


Fig. 4

Dosing errors (%)

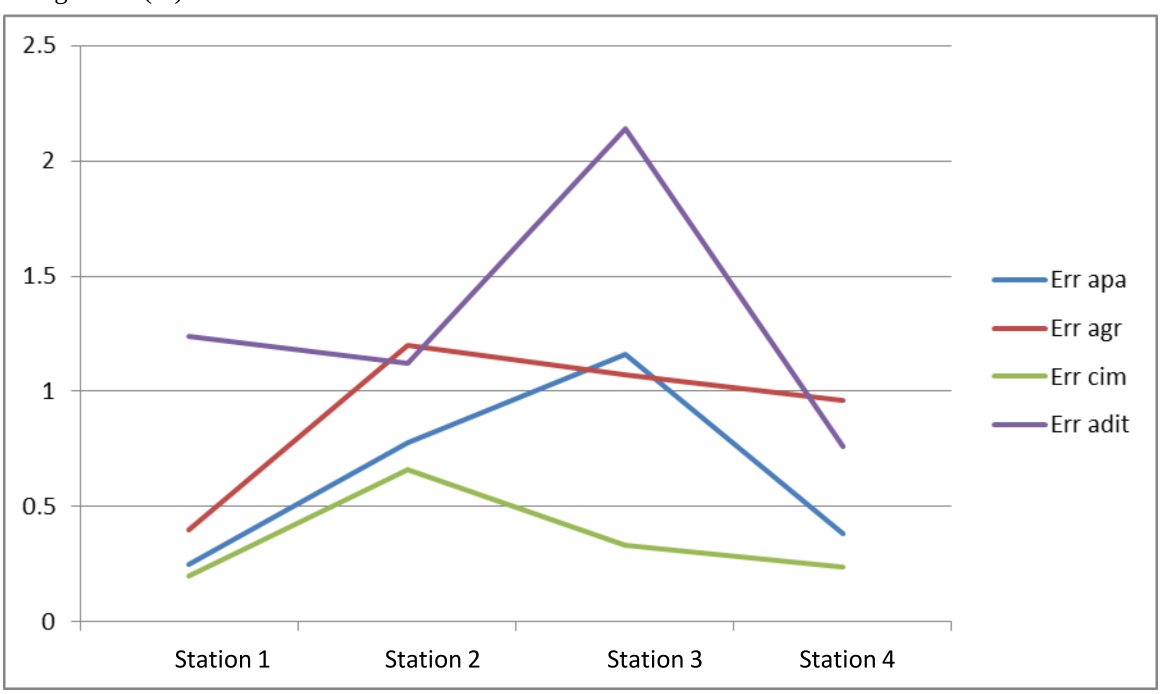


Fig.5
Dosing errors (%)

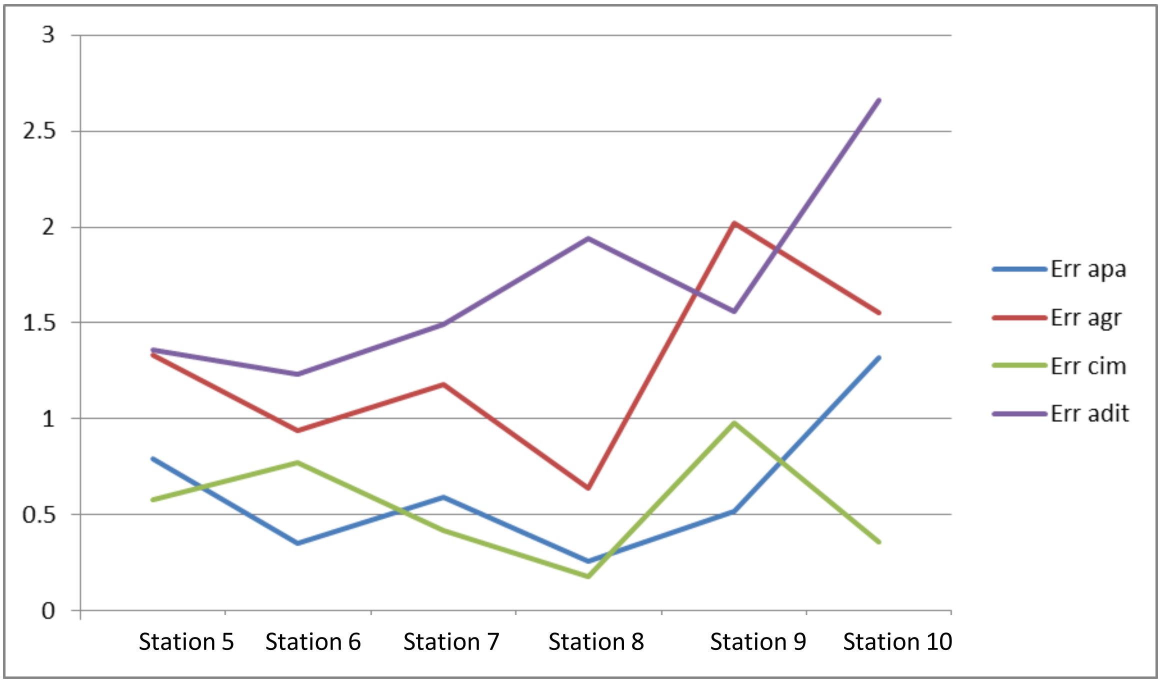


Table 3

Station	1	2	3	4	5	6	7	8	9	10
n_{ct}	20.7	26.4	20	25	15	15	20.7	20.7	25	25
n_{det}	20.4	25.9	19.9	24.8	14.7	14.3	20.6	20.2	24.3	24.1

Conclusions

The ten concrete stations chosen to compair were of more recently date of manufacture, four from them having terms use of 12-14 years, the others having manufacture years between 2012-2019. Chosen manufacturing companies were reprezentative foreigner companies in eight from analyzed cases, two from the concrete stations being romanian.

All station chosen to compare have dosing gravimetric systems at all concrete components and original automatic command system. Four from these stations have correlation devices in command system software for concrete consistency with absorbed power of mixer engine, the operator can achive the mixing time adjustment with consistency and class concrete during the batches preparation.

At these concrete stations were found differences something bigger between prescribed and effective mixing times (see table 2 and figures 1, 2 and 3).

At the other concrete stations a such a correlation can be done experimental, based on the laboratory results and then by the reset of mixing times necessary for respective concrete class in the recipes from software (where required).

The comparison of mixing times and cycle durations precribed in recipes and technical data manuals with the values effective measured during the concrete preaparation(see graphs from figures 1, 2, 3) leads to the following conclusions :

- effective mixing time is bigger than those prescribed in recipe in all cases presented; clear differences can be observed only in the case of the four stations whose software can determine automatically the consistency;

- the effective cycle durations are bigger than those prescribed in prospectus with 6-20 seconds, depending on the prepared concrete class, operational capacity of the mixer, mixer type and the analyzed station manufacture year; this is because:

- at bigger use durations, it appears wear and also in operation blockings;

- cycle standard duration is determined for mixer useful capacity, and operational capacity (smaller than the useful one in the most cases) can influence the effective cycle duration in the sense of its decrease;

- the prepared concrete class can influence the cycle duration either due the mixing time variation, or due the variation of the mixer loading-descharging durations;

- the mixer type of the concrete station can influence preparation cycle duration by factors such as: rotation speed, pallets arrangement mode, number of axis with pallets, agitators additionally mounted, and so on.

The mixers of the chosen concrete stations had different capacities and various pallets arrangement mode (with a vertical axis with two vertical axis and with two horizontal axis). The rotation speeds of the axis with pallets fell within the limit of $\pm 5\%$, in relation to the values prescribed in the technical data manual, being closer of these in the case of the new stations, with a lower degree of equipments wear.

At setting of mixing time in the recipe should take into account by the recommended duration of the mixer manufacturer, by the capacity and mixer rotation speed, the mode of pallets arrangement and especially by the concrete recipe (the mixture density and the report water/cement).

Prepared concrete classes were in the most analyzed cases C12/15, C16/20, C20/25, or C 25/30.

Dosing errors determined and shown in table 2 and in the graphs from figures for all ten stations analyzed have led to the next conclusions:

- The dosing errors determinated for the four components fell within the values prescribed by CP 012/1-2007;

- The littlest dosing errors have been obtained usual at cement dosing, and the biggest at the additive dosing;

- The little dosing errors for water and cement (less than 2%) offer to the concrete stations the possibility to respect the deviation by 0.02 imposed by CP 012/1-2007 for water/cement ratio.

4. The study of mixing systems, the mixing efficiency

The mixers commonly used in automated concrete stations have capacities by 1.0-2.25 cubic meters on batch.

Exemples of mixers found at various concrete stations manufacturers:

- LIEBHERR mixers with vertical axis with capacity of 0.5 c.m. and 1.0 c.m., with rotation speed of 26 rot/min ;
- LIEBHERR mixers with vertical axis, of 2.0 c.m. and 2.25 c.m. fitted with agitators, mounted on one of the arms, used for the increasing of the mixing process efficiency; rotation speed is 20.7 rot /min and of the agitator is 40 rot/min;
- LIEBHERR mixers with two horizontal axis with capacities of 2.25 and 2.5 c.m., with rotation speed of 20.7 rot/min;
- SICOMA mixers with two horizontal axis with capacity of 1.5 c.m. and rotation speed of 25 rot/min ;
- SICOMA mixers with two vertical axis ith capacity of 1.5 c.mwith rotation speed of 15 rot/min;
- SIMEM mixers with two horizontal axis with capacity of 1.5 c.m., having rotation speed of 25 rot/min .

The mixing process efficiency depends on: the number of axis with pallets, their arrangement in horizontal /vertical plane, the surface, the form and the number of kneading pallets, their tilt angles in horizontal /vertical plane, with or without agitators.

In order to obtain high quality concrete the compliance of manufacturer regulations relating to mixing time is imperative.

Exemples of values recommended for mixing time:

- the LIEBHERR mixers have mixing times recommended of 30 seconds, the duration ca be enlarged in relation by the load(bigger volume of the batch or drier concrete);
- the SICOMA and OCMER mixers have mixing times recommended of 40 seconds for wet concrete and of 60 seconds for dry concrete;
- SIMEM mixers have mixing times recommended in relation with the mixing capacity, for fluid concrete of 30-35 seconds and 60 seconds for dry concrete.

Another recommendation relating to mixing time is the one concern the additive use; at mixing on cold weather and using a certain additive (for exemple additive SIKA model) it is recommended that mixing time to be increased by 10 seconds.

Mixing efficiency, in order to obtain homogeneus mixtures

In the case of the mixers with one or two vertical axis the efficiency depends on:

- the agitators additional mounted (in the case of the volumes bigger than 1.0 c.m.);
- rotation speed of rotors or axis with pallets (bigger in the case of smaller volume);
- the number of kneading pallets and the arrangement mode on the axis with pallets.

In the case of two horizontal axis mixers, the kneading process efficiency depends on on the number of pallets and speed rotation.

The mixers classification by type of dimensions

The mixers found usually at concrete producers from Romania have capacities between 0.5-2.5 c.m.

By the mode of pallets arramgement and by the number of axis, we can list:

- mixers with a vertical axis with pallets with capacity of 0.5 c.m, 1.0 c.m, 2.0 c.m, 2.25 c.m;
- mixers with two vertical axis with pallets with capacity of 1.0 mc, 1.5 mc, 2 mc;
- mixers with two horizontal axis with pallets with capacity de 1.0 c.m, 1.5 c.m, 2.0 c.m;
- mixer with a horizontal axis and screw with capacity of 1.0 c.m.

4.1. Study of mixers with one or two vertical axis with pallets

4.1.1 The case of the mixer with two vertical axis

The calculation of necessary power to act each axis with pallets, considered equal with the power of each drive motor, using the relation :

$P_m = M\omega$, (2) from which it results:

$P_m = \frac{k_m n \sum r_{mi}(S_i cos\alpha_i cos\beta_i + A_{si})}{95500\, \eta_{tr}}$ $[kW]$, (3)

relation from which it is determined k_m, like average specific mixing resistance, determined for each axis with pallets;

In relation (3) n is the rotation speed of the axis with pallets (rot/min), η_{tr} is the efficiency of transmission engine - axis with pallets of the mixer, S_i represents the pallets surface, α_i and β_i pallets titlt angles in vertical/horizontal plane, and A_{si} represents the surface of mixing arm portion, existent inside the material during the mixing and it is determined with relation(4):

$A_{si} = \frac{\pi d}{2}\left(h_m - h_p cos\beta i\right)[cm^2]$, (4),

in which d is arm mixer diameter, h_m is the hight of material layer, and h_p is pallet hight.

Mixing resistance determination for the (n x 2) pallets (n pallets on each axis) is made considering pallets average radius: $r_{m1} = r_{m2} = \frac{1}{n}\sum r_i$ $[cm]$ (5);

For each pallets it applies the relation : $k_i = \frac{r_i}{r_m} k_m [daN/cm^2]$, (6)

Tangential speeds calculation of each axis pallets, is made by relation:

$v_i = \omega r_{ie} = \frac{\pi n}{30} r_{ie} [m/s]$, (7),

In which r_{ie} represents the outer radius (tangential) of each pallet.

4.1.2 The case of vertical axis mixer with pallets, with or without agitator

In the case of vertical axis mixer with pallets, it applies the calculation relation from the point 2.1, with the difference that all n pallets and the agitator additionally mountedse are placed on a single axis, acted by a single electrical motor and therefore the relation (6) become

$r_m = \frac{1}{n}\sum r_i$ [cm] (8)

And in relation (3) it will be introduced the actuating power of the n pallets (not that one necessary agitator driving).

4.2. The study of the mixer with two horizontal axis

The necessary power to actuate each axis with pallets, considered being equal with the drive engine power, using relation (2), $P_m = M\omega$, we obtain:

$$P_m = \frac{\psi z n k_m b\left(r_e{}^2 - r_i{}^2\right)}{2x\ 95500 x \eta_{tr}} x\ cos\alpha[kW], (9)$$

in which: ψ = 0,6…0,7 is filling coefficient of the vat, z is the total number of pallets with the wide b, tilted with the angle α in relation to the longitudinal plane of the vat, r_e and r_i are outer and inner radius of the pallets arranged in vertical/radial plane, η_{tr} is the efficiency of transmission engine - mixer; k_m represents average specific mixing resistance, equal with mixing resistance for each pallet, because in this case of mixer type we can consider: $r_i = r_m$

Tangential speeds, equals for the twelve pallets are determined with relation (7), in which $r_{ie} = r_e$

EXEMPLES

4.11. The mixer of 1.5 cm with two vertical axis, shown in figure 6 has the next technical characteristics :

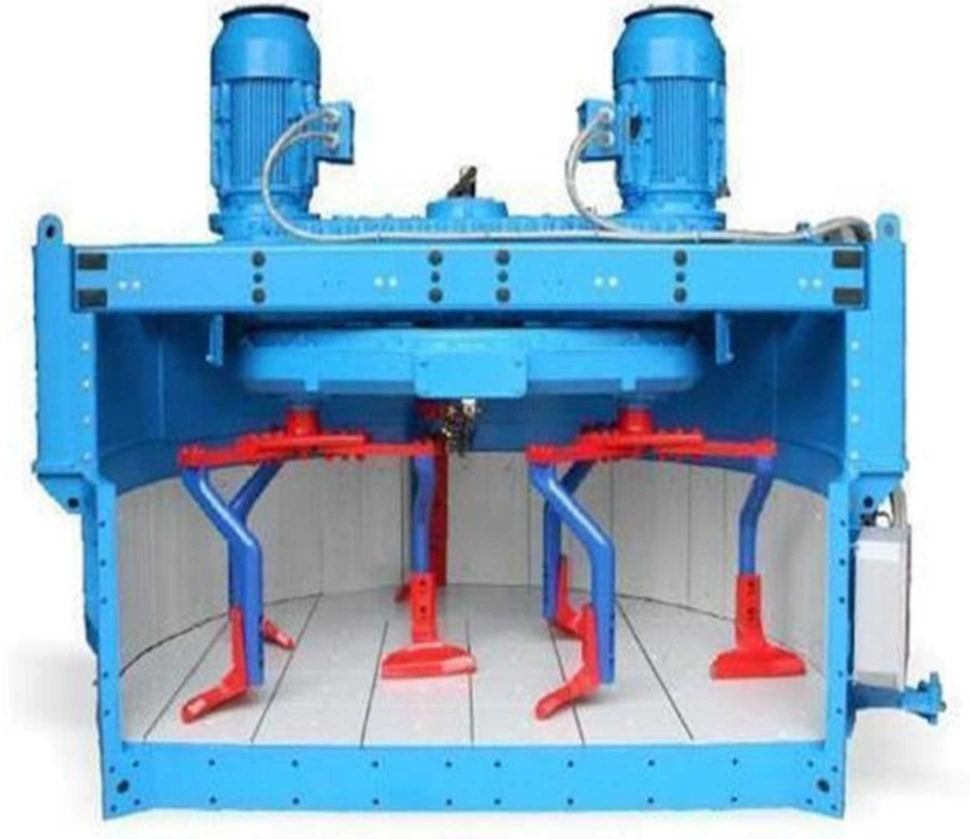
- drive engines power 30+30 kW;
- pallets number 3+3, the rotation speed of the two rotors 14.3 rot/min.

Considering: d= 5 cm, h_m = 46.6 cm, and h_p =12.8 cm, S_i= 332 cm^2 , α_i=40^0 , β_i= 25^0 and pallets radiuses on the two axis being of 62, 60 and 58 cm, by applying relation (4) we obtain:

A_{si}= 274 cm^2; $S_i cos\alpha_i cos\beta_i$= 230 cm^2

$\sum r_{mi}(S_i cos\alpha_i cos\beta_i + A_{si})$ = 90720 cm^3, for each axis of the mixer

Figure 6



In relation (3), introducing the drive engine power at one axis of 30 kW, considered as like the three working pallets drive power (regardless the power necesarry for scraper pallets) and $\eta_{tr} = 0{,}85$ it will result for maximum specific mixing resistance, the value

$$\boldsymbol{k_m = 1{,}88\ daN/cm^2}$$

Applying relation (6) we obtain the next values of specific mixing resistance pentru for the three pallets on each axis : k_1= 1.94 daN/cm^2; k_2= 1.88 daN/cm^2; k_3 = 1.81 daN/cm^2.

Tangential speeds for the three pallets, determined with relation (7) are the next:

v_1= 1.1 m/s; v_2= 1.06 m/s; v_3= 1.02 m/s

4.2.1 The mixer of 1.5 c.m. with two horizontal axis, presented in figure 7, have the next technical characteristics:

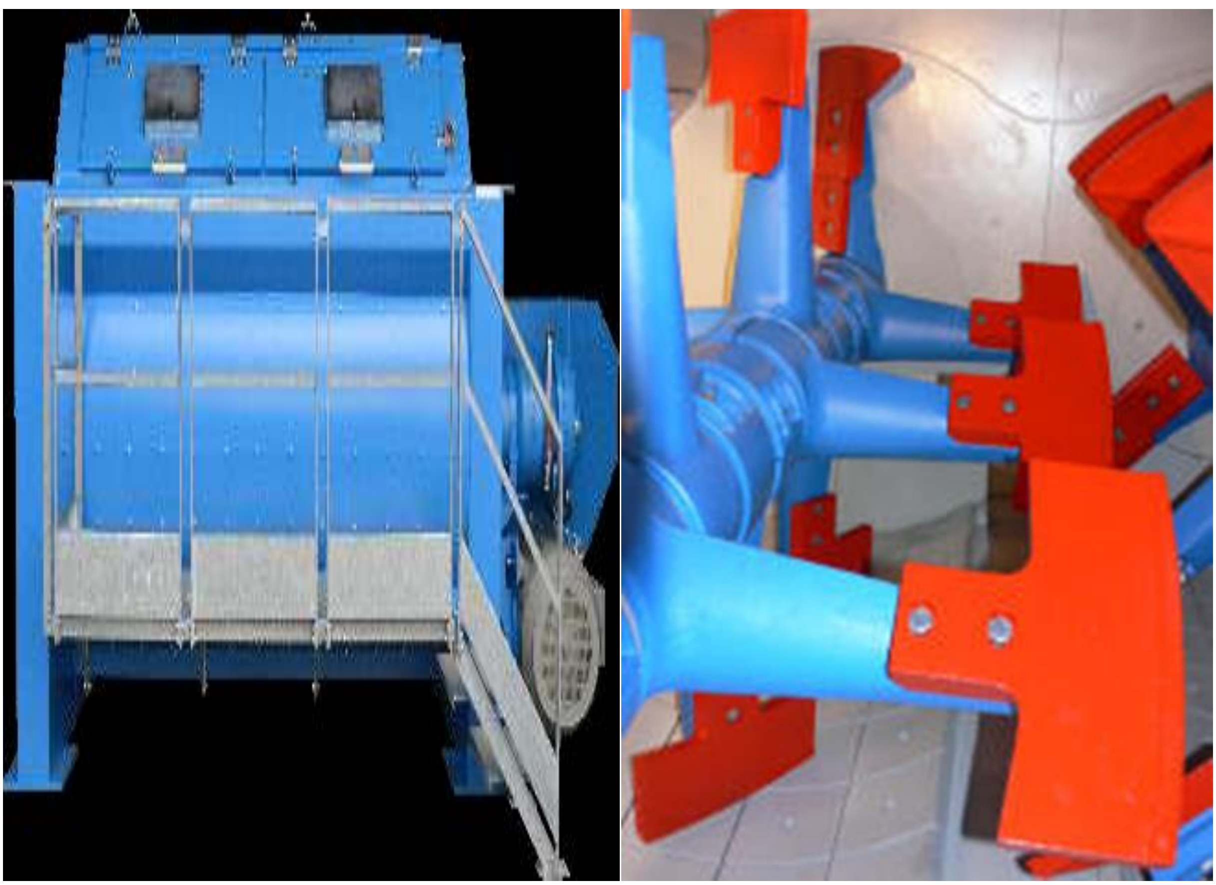
The installed power of the engine which actuates the two axis is 55,2 kW, working pallets number 6+6= 12, actuating power of active pallets is 55,2 kW (regardless by consumption energy by the scraper pallets) rotation speed of the two axis with pallets 25 rot /min.

Introducing in relation (9) the values: ψ = 0,7, z =12 , b = 28 cm, α = 40^0, r_e = 50 cm, r_i = 35 cm and η_{tr} =0,85, we obtain for average specific mixing resistance the value

$\boldsymbol{k_m = 1.56\ daN/cm^2}$

Pallets tangential speed, resulted after applying relation (7) is: $\boldsymbol{v}$ **= 1.31 m/s**

Figure 7



4.12. The mixer of 2.25 cm with a vertical axis with five pallets and agitator , shown in figure 8, has the next technical characteristics: installed power of the actuating engine 90 kW, actuating power of the five pallets (without scraper pallets and agitator) **70 kW**, mixer rotation speed 20.7 rot/min

Considering: d= 5,2 cm, h_m = 51,8 cm, and h_p =12 cm, S_i= 336 cm^2

α_i=40⁰ , β_i= 25⁰ and pallets radiuses having the values: 142, 128, 114, 103 and 88 cm, by applying the relations we obtain the next results:

A_{si}= 325 cm^2; $S_i cos\alpha_i cos\beta_i$= 233 cm^2

$\sum r_{mi}(S_i cos\alpha_i cos\beta_i + A_{si})$= 320850 cm^3, for the five mixer pallets;

In relation (3), introducing actuating engine power for the five pallets of 70 kW and η_{tr} = 0.85 it will result for maximum specific mixing resistance the value

$\boldsymbol{k_m = 0.86\ daN/cm^2}$

Aplying relation (6) we obtain the next values of maximum specific mixing resistance for the five pallets:

k_1= 1.06 daN/cm^2; k_2 =0.95 daN/cm^2; k_3 = 0.85 daN/cm^2; k_4=0.77 daN/cm^2 ;
k_5= 0.65 daN/cm^2

Tangential speeds for the five pallets are determined with relation (7) are the next: v_1= 3.37 m/s; v_2=3.03 m/s; $\boldsymbol{v_3}$= 2.70 m/s; v_4= 2.47 m/s; v_5= 2.16 m/s

4.22. Mixer of 2.25 mc with two horizontal axis, shown în figure 9 has the next technical characteristics:

installed power of the actuating engine 75 kW, pallets number 12, actuating power of the twelve pallets (without scraper pallets) **70 kW**, rotor sped 20.7 rot/min;

Introducing in relation (9) : ψ = 0,7, z =12 , b = 28 cm, α = 40⁰, r_e = 57 cm, r_i = 42 cm and η_{tr} = 0,85 we obtain for average specific mixing resistance the value $\boldsymbol{k_m = 2.05\ daN/cm^2}$

Tangential speeds resulted at pallets: $\boldsymbol{v}$ **= 1.3 m/s**

Similarly have been determined tangential speeds and mixing resistances for mixers with two horizontal axis with pallets, of 1.0 cm (engine power 37 kW, rotors speed 25 rot/min, 8 pallets) and with capacity of 2.0 cm (engine power 2x37 kW, rotors speed 25 rot/min, 12 pallets):

- for mixers with two horizontal axis of 1.0 cm**: v = 1.17 m/s**, $\boldsymbol{k_m}$**= 1.47** $\boldsymbol{daN/cm^2}$;
- for mixers with two horizontal axis of 2.0 cm: **v = 1.30 m/s**, $\boldsymbol{k_m}$**= 1.78** $\boldsymbol{daN/cm^2}$;

Using the relations from point 4.1.1 it is determined :

- for mixer with two vertical axis of 1.0 cm (engine power 45 kW, rotor speed 20 rot/min, 6 pallets) : **v = 1.15 m/s**, $\boldsymbol{k_m}$**= 1.38** $\boldsymbol{daN/cm^2}$
- for mixer with two vertical axis of 2.0 cm (engine power 2x45 kW, rotor speed 15 rot/min, 6 pallets : **v = 1.30 m/s**, $\boldsymbol{k_m}$**= 1.62** $\boldsymbol{daN/cm^2}$

Figure 8

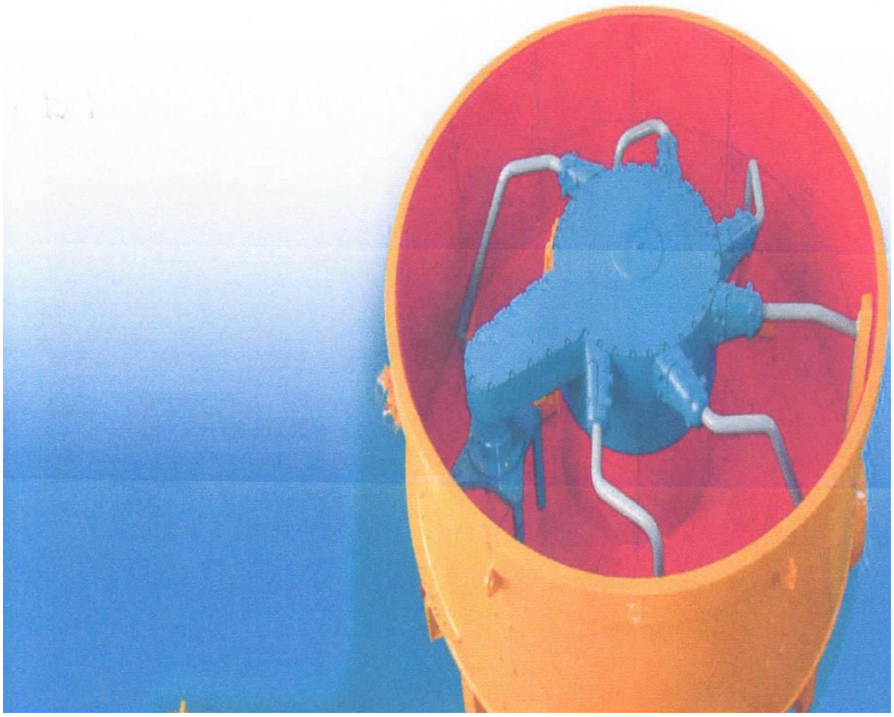


Figure 9

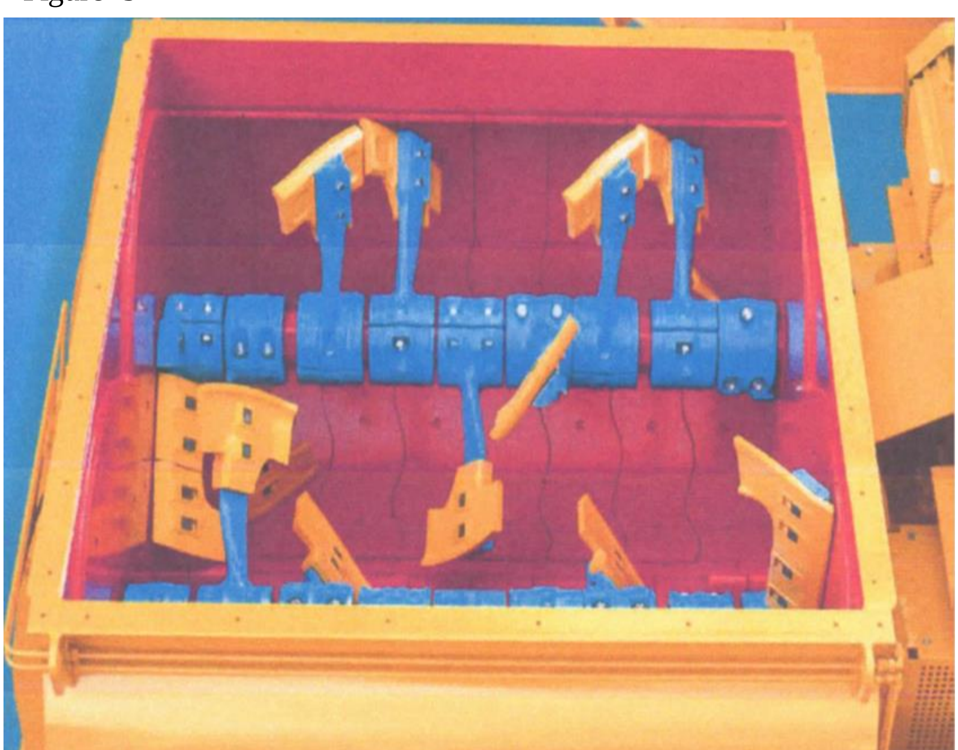


Figure 10

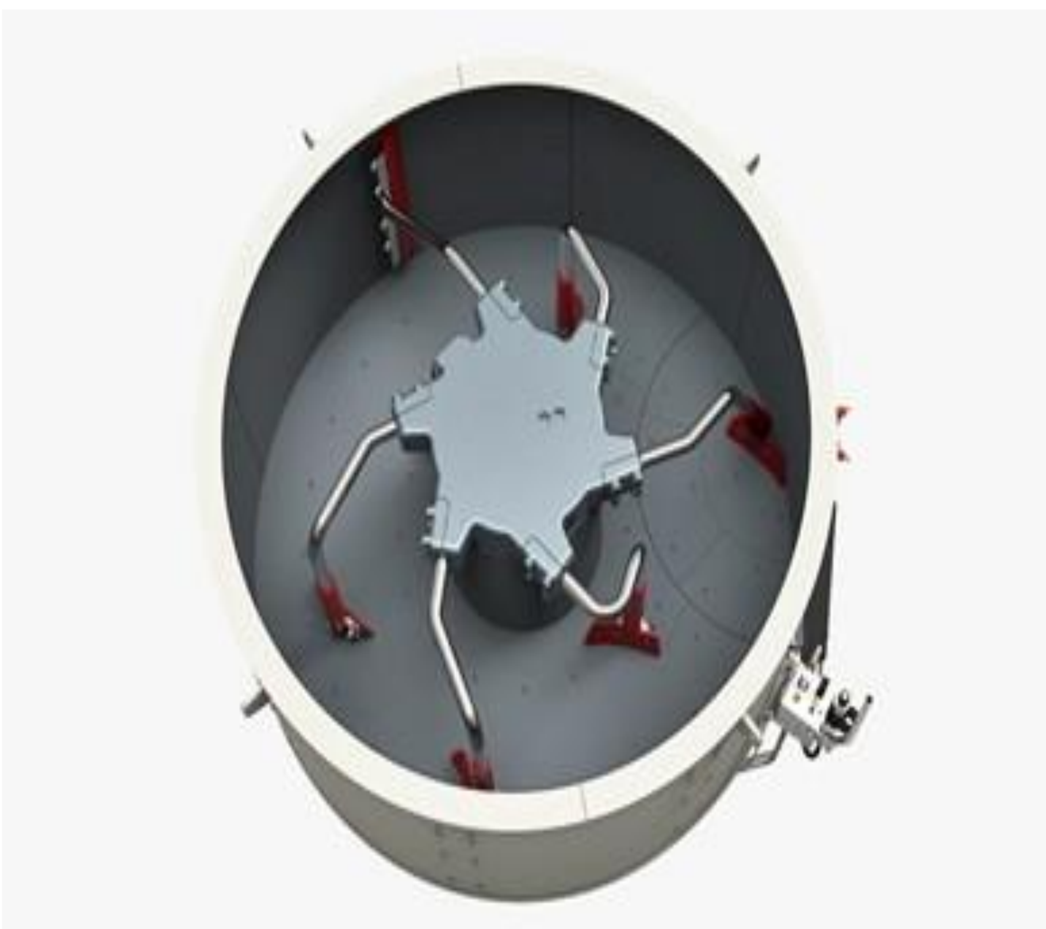


Figure 11

Using the relations from point 4.1.2 it is determined :

- for mixer with one vertical axis of 0.5 cm, shown in figure 10 (engine power 22 kW, rotor speed 26.2 rot/min, 5 pallets) : **v = 2.38 m/s**, $\boldsymbol{k_m}$**= 0.44** $\boldsymbol{daN/cm^2}$;

- for mixer with one vertical axis of 1.0 cm, shown in figure 11 (engine power 37 kW, rotor speed 26.4 rot/min, 5 pallets : **v = 2.75 m/s**, $\boldsymbol{k_m}$**= 0.54** $\boldsymbol{daN/cm^2}$;

- for mixer with one vertical axis of 2.0 mc (engine power 75 kW, rotor speed 20.7 rot/min, 5 pallets + agitator) : **v = 2.80 m/s**, $\boldsymbol{k_m}$**= 0.78** $\boldsymbol{daN/cm^2}$;

5. Variation mode of time mixing with the compression strength

The mixing time depends on several factors, the most important being:

- recommended duration by manufacturer mixer , depends on prepared concrete types (fluid or dry);

- recommended duration by manufacturer of the used additive, at concrete preparation in cold weather;

- recipe factor of concrete class (dependent on: variation mode of mixture density from mixer and the report water/cement when moving from one concrete class to another; these depends on the quantities prescribed at materials, the dossing errors and the imposed concrete consistency class – maximum dimension of aggregate);

- mixer factor, dependent on: mixing system, useful capacity, actuating engine power, speed rotation and and the pallets arrangement mode;

- a factor specific to the use in cold weather or at preparation of some concretes which will be subjected on thermal treatment(the case of concretes used to the bridge beams manufacture);

For any recipe in part from a concrete testing laboratory, we have various quantities , various reports water/cement, variable aggregate particle size (the use of the size particle > 16 mm), variable apparent densities, variable mixture densities.

The recipe factor corresponding to concrete class and specifical to the recipe issued by the laboratory. The variation mode of water/cement report with the concrete class and of the apparent density, implicitly of real density of the material in the mixer is prescribed in concrete recipes nomenclature.

The mixer factor is specifical to the mixer type used in respective concrete station. It is closely related by the two factors of the kneading process quality, the pallets tangential speed and the average mixing resistance.

The corelation mode of compression strength with the mixing time can be made starting with the minimum (recommended) value and from compression strength, corresponding to reference concrete, considered C 8/10. The recipe factor of the concete class X , introduced in relation between mixing time and compression strength, can be determined either in relation to reference concrete class C 8/10 or with the concrete class previous to the class X(X-1).

Mixer factor variation. The adoption necessity of a overall factor

Mixer factor is determined for each mixer in part, taking into account by the three parameters:

- Specific mixing resistance which determine resistance factor, like a ratio between the specific resistance of respective mixer and a maximum mixing resistance for respective mixing system;
- Kneading speed which determine speed factor, calculated like the difference between optimum speed for respective mixing system and the average kneading speed of the respective mixer, reported to a reference speed (1.0 m/s);
- the mixer filling factor with material, like ratio between batch capacity and mixer useful mixer capacity.

For mixers with verical axis this maximum resistance it is considered 1.0 daN/cm^2, and for mixers with two axis (vertical or horizontal) it is considered the value 2.0 daN/cm^2

For mixers with verical axis the pallets tangential optimum speed it is considered 3 m/s, and for mixers with two axis (vertical or horizontal) optimum speed it is considered 1.5 m/s

The filling factor , theoretically permanent variable, it is considered for all mixers 0.75, like average ratio operational capacity /batch and mixer useful capacity.

At the concrete preparation, the absorbed power by electric motor and the rotor speed (implicitly kneading speed) vary permanently and therefore it appears the need to define an overall factor, like a multiplication of the three factors (resistance, speed, filling capacity).

At his calculation will be taken into account by: the engine power, the idle rotation speed , the pallets arrangement radiuses, the surfaces and the number of pallets, the mixer capacity.

Recipe factor variation

The recipe factor varies permanently,because the material density from the mixer due to the change of material quantities from a concrete class to another or due to the change of water/cement report from a batch to another, during concrete preparation (in the case when the mixture has a too much consistency).

The recipe factor can be determined either reporting the X concrete class to the previous concrete class X-1,or reporting the X concrete class to the reference class, considered C8/10.

5.1. The relation between mixing time and the compression strength

$t_m = t_0 k_1 + t_0 k_2 \left(1 - \frac{R_{c0}}{R_c}\right)$ (10)

$R_{c0} = 10\ \mathrm{N}/mm^2$

$k_2 = f_m + f_r$, (11)

$f_m = k_{rez} k_{vit} k_u$ (12)

$f_r = 1 - \frac{\rho_x}{\rho_{x-1}} x \frac{a_x/c_x}{a_{x-1}/c_{x-1}}$ (13)

or $f_r = 1 - \frac{\rho_x}{\rho_0} x \frac{a_x/c_x}{a_0/c_0}$ (14)

For f_m considered equal with zero, we have the relation:

$\boldsymbol{k_2 = f_r = 1 - \frac{\rho_{x-1}}{\rho_x} x \frac{a_x/c_x}{a_{x-1}/c_{x-1}}}$ (15)

Mixers with vertical axis:

1) Useful capacity 0.5 cm**,**

$\boldsymbol{k_{rez} = \frac{k_{sp}}{k_{max}} = \frac{0.44}{1,0}} = 0.44$

$\boldsymbol{k_{vit} = \frac{v_o - v_m}{v_{ref}} = \frac{3-2.4}{1}} = 0.6$

$k_u = 0.75$,the filling factor, available for all cases

It results**: $\boldsymbol{f_m}$=0.19**

2) Useful capacity 1.0 cm,

$k_{rez} = \frac{k_{sp}}{k_{max}} = \frac{0,54}{1,0} = 0.54$

$k_{vit} = \frac{v_o - v_m}{v_{ref}} = \frac{3-2.7}{1} = 0.3$**,** it results: **$\boldsymbol{f_m}$= 0.12**

3)Useful capacity 2.0 cm

$k_{rez} = \frac{k_{sp}}{k_{max}} = \frac{0,80}{1,0} = 0.80$

$k_{vit} = \frac{v_o - v_m}{v_{ref}} = \frac{3-2.8}{1} = 0.2$**,** it results: **$\boldsymbol{f_m}$=0.12**

Mixers with two verical axis

1)Useful capacity: 1.0 cm**,**

$\boldsymbol{k_{rez}}=\frac{\boldsymbol{k_{sp}}}{\boldsymbol{k_{max}}}=\frac{\mathbf{1.38}}{\mathbf{2,0}}= 0.69$

$\boldsymbol{k_{vit}}=\frac{\boldsymbol{v_o-v_m}}{\boldsymbol{v_{ref}}}=\frac{\mathbf{1.5-1.15}}{\mathbf{1}}= 0.35$

k_u= 0.75, the filling factor, available for all cases

It results**:** $\boldsymbol{f_m}$**=0.18**

2) Useful capacity 1.5 cm,

$k_{rez}=\frac{k_{sp}}{k_{max}}=\frac{1.88}{2.0}= 0.94$

$k_{vit}=\frac{v_o-v_m}{v_{ref}}=\frac{1.5-1.0}{1}= 0.50$**,** it results: $\boldsymbol{f_m}$**=0.35**

3) Useful capacity 2.0 cm

$k_{rez}=\frac{k_{sp}}{k_{max}}=\frac{1.62}{2.0}= 0.81$

$k_{vit}=\frac{v_o-v_m}{v_{ref}}=\frac{1.5-1.3}{1}= 0.2$**,** it results: $\boldsymbol{f_m}$**=0.12**

Mixers with two horizontal axis

1) Useful capacity : 1.0 cm

$\boldsymbol{k_{rez}}=\frac{\boldsymbol{k_{sp}}}{\boldsymbol{k_{max}}}=\frac{\mathbf{1.47}}{\mathbf{2.0}}= 0.73$

$\boldsymbol{k_{vit}}=\frac{\boldsymbol{v_o-v_m}}{\boldsymbol{v_{ref}}}=\frac{\mathbf{1.5-1.17}}{\mathbf{1}}= 0.33$

k_u= 0.75, the filling factor, available for all cases

It results**:** $\boldsymbol{f_m}$**=0.18**

2) Useful capacity 1.5 cm,

$k_{rez}=\frac{k_{sp}}{k_{max}}=\frac{1.56}{2.0}= 0.78$

$k_{vit}=\frac{v_o-v_m}{v_{ref}}=\frac{1.5-1.17}{1}= 0.33$**,** it results: $\boldsymbol{f_m}$**=0.19**

3) Useful capacity 2.0 cm

$k_{rez}=\frac{k_{sp}}{k_{max}}=\frac{1.78}{2,0}= 0.89$

$k_{vit}=\frac{v_o-v_m}{v_{ref}}=\frac{1.5-1.3}{1}= 0.2$**,** it results: $\boldsymbol{f_m}$**=0.13**

Recipe factor calculation

The recipe factor, is determined with relation 13 or with relation 14

f_r= 1 - $\frac{\rho_{x-1}}{\rho_x}$ x $\frac{a_x/c_x}{a_{x-1}/c_{x-1}}$ (13)

or:

f_r = 1- $\frac{\rho_0}{\rho_x}$ x $\frac{a_x/c_x}{a_0/c_0}$ (14)

For the class C 8/10, it is considered : a/c= 0.72 şi $\boldsymbol{\rho_{x-1}}$ = 2345 kg/cm;

Applying the relation (13)

For C12/15, a/c= 0.68 and $\boldsymbol{\rho_x}$= 2348 kg/mc; rezultă $\boldsymbol{f_r}$= 0.056
For C 16/20, a/c=0.64 and $\boldsymbol{\rho_x}$= 2355 kg/mc; $\boldsymbol{f_r}$=0.061
For C 18/22,5, a/c=0.60 and $\boldsymbol{\rho_x}$= 2353 kg/mc; $\boldsymbol{f_r}$=0.061
For C 20/25, a/c=0.56 and $\boldsymbol{\rho_x}$= 2359 kg/mc; $\boldsymbol{f_r}$=0.085
For C 25/30, a/c=0.51 and $\boldsymbol{\rho_x}$= 2355kg/mc; $\boldsymbol{f_r}$=0.087
For C 30/37, a/c=0.47 and $\boldsymbol{\rho_x}$= 2371kg/mc; $\boldsymbol{f_r}$=0.085
For C 32/40, a/c=0.44 and $\boldsymbol{\rho_x}$= 2376 kg/mc; $\boldsymbol{f_r}$=0.066
For C 35/45, a/c=0.41 and $\boldsymbol{\rho_x}$= 2379 kg/mc; $\boldsymbol{f_r}$=0.069
For C 40/50, a/c=0.39 and $\boldsymbol{\rho_x}$= 2388 kg/mc; $\boldsymbol{f_r}$=0.052
For C 50/60, a/c=0.36 and $\boldsymbol{\rho_x}$= 2398 kg/mc; $\boldsymbol{f_r}$=0.080

Applying the relation (14)

For C12/15, a/c= 0.68 and $\boldsymbol{\rho_x}$= 2348 kg/mc; rezultă $\boldsymbol{f_r}$= 0.056
For C 16/20, a/c=0.64 and $\boldsymbol{\rho_x}$= 2355 kg/mc; $\boldsymbol{f_r}$=0.114
For C 18/22,5, a/c=0.60 and $\boldsymbol{\rho_x}$= 2353 kg/mc; $\boldsymbol{f_r}$=0.169
For C 20/25, a/c=0.56 and $\boldsymbol{\rho_x}$= 2359 kg/mc; $\boldsymbol{f_r}$=0.226
For C 25/30, a/c=0.51 and $\boldsymbol{\rho_x}$= 2355kg/mc; $\boldsymbol{f_r}$=0.294
For C 30/37, a/c=0.47 and $\boldsymbol{\rho_x}$= 2371kg/mc; $\boldsymbol{f_r}$=0.354
For C 32/40, a/c=0.44 and $\boldsymbol{\rho_x}$= 2376 kg/mc; $\boldsymbol{f_r}$=0.396
For C 35/45, a/c=0.41 and $\boldsymbol{\rho_x}$= 2379 kg/mc; $\boldsymbol{f_r}$=0.438
For C 40/50, a/c=0.39 and $\boldsymbol{\rho_x}$= 2388 kg/mc; $\boldsymbol{f_r}$=0.468
For C 50/60, a/c=0.36 and $\boldsymbol{\rho_x}$= 2398 kg/mc; $\boldsymbol{f_r}$=0.511

5.2 The relations use for different mixers type

a) At mixers with vertical axis

0.5 cm : C 16/20, R_c = 24.4 N/mm^2

t_m=t_0k_1+$t_0k_2\left(1-\frac{R_{c0}}{R_c}\right)$

t_0=30 sec, k_1=1

Calculated values for mixing time:

t_{m1}= 30+ 30(0.19+ 0.114) (1 - $\frac{10}{24.4}$)=35.4 sec, taking into account by the mixer factor and by the recipe factor calculated with relation (14)

t_{m2}= 30+ 30 x 0,061 (1 - $\frac{10}{24.4}$)= 31 sec, taking into account only by the recipe factor calculated with relation (13)

Measured value : 30.68 sec

t_m recommended by the mixer manufacturer 30 sec

1.0 cm: C 12/15, R_c = 18.4 N/mm^2; C 16/20, R_c = 28.9 N/mm^2; C 20/25, R_c= 32.9 N/mm^2; C 25/30, R_c = 38.7 N/mm^2; C 30/37, R_c = 48.7 N/mm^2; C 35/45, R_c= 52.7N/mm^2

t_0=30 sec, k_1=1

Calculated values for t_{m1} (sec):32.4; 34.5; 37.2; 39.2; 41.2; 43.5, taking into account by the mixer factor and by the recipe factor calculated with relation (14)

Calculated values for t_{m2}(sec) taking into account only by the recipe factor calculated with relation (13): 30.8; 31.2; 31.8; 31.9; 32.02; 33.1

Measured values: 31.15; 31.42; 31.55; 32.31; 31.67; 32.43

C12/15, R_c = 23.8 N/mm^2, t_0=35 sec, k_1=1; t_{m1}= 38.6 sec; t_{m2}= 36.1 sec; meas. val 35.72 sec
C 18/22,5, R_c = 30.4 N/mm^2; t_0=40 sec, k_1=1; t_{m1}= 47.7 sec; t_{m2}= 41.6 sec; meas. val. 40.52 sec
C 20/25, R_c = 35.4 N/$mm^2$$t_0$=45 sec, k_1=1; t_{m1}= 56.2 sec; t_{m2}= 47.7 sec; meas. val. 46.12 sec
t_m recommended by the mixer manufacturer 30 sec

2.0 cm : C 25/30, R_c = 36.0 N/mm^2

t_0=30 sec, k_1=1

t_{m1}= 38.9 sec

t_{m2}= 31.8 sec

Measured values: 32.77 sec

t_m recommended by the mixer manufacturer 30 sec

b)Mixers with two vertical axis

1.0 cm

C16/20, R_c = 23.8 N/mm^2; C 20/25, R_c = 29.0 N/mm^2; C 25/30, R_c = 36.8 N/mm^2
t_0=30 sec, k_1=1
t_m recommended by the mixer manufacturer 40 sec
Calculated values:
t_{m1}= 35.1 sec; 38 sec; 40.3 sec;
t_{m2}= 31.05 sec; 31.7 sec; 31.9 sec;
Measured values: 30.47 sec; 30.51 sec; 31.02 sec

1.5 cm

C16/20, R_c = 29.9 N/mm^2; C 20/25, R_c = 33.4 N/mm^2; C 25/30, R_c = 41.8 N/mm^2
t_0=40 sec, k_1=1
Calculated values:
t_{m1}= 52.34 sec; 56.1 sec; 59.6 sec;
t_{m2}= 41.6 sec; 42.4 sec; 42.6 sec;
Measured values: 40.67 sec; 41.25 sec; 41.33 sec
t_m recommended by the mixer manufacturer 40 sec

2.0 cm

C 12/15, R_c = 19.2 N/mm^2; C 30/37, R_c = 46 N/mm^2;
t_0=40 sec, k_1=1
Calculated values:
t_{m1}= 43.4 sec; 54.8 sec;
t_{m2}= 40.22 sec; 42.7 sec;
Measured values: 40.47 sec; 41.55 sec;

C 40/50, R_c = 54.7 N/mm^2; C 50/60, R_c = 64.3 N/mm^2
t_0=60 sec, k_1=1.5, for special concretes subjected to thermal treatment further
t_{m1}= 118.83 sec; 121.95 sec;
t_{m2}= 92.5 sec; 94.05 sec;
Measured values: 120.12 sec; 120.26 sec;
t_m recommended by the mixer manufacturer 60 sec

c) Mixers with two horizontal axis

1.0 cm

C 16/20, R_c = 21.63 N/mm^2 , C 20/25, R_c = 27.27 N/mm^2, C 25/30, R_c = 31.25 N/mm^2,
t_0=45 sec, k_1=1, t_m recommended by the mixer manufacturer 30 sec
Calculated values:
t_{m1}= 52.1 sec**;** 56.7 sec; 59.5 sec;
t_{m2}= 46.4 sec; 47.4 sec; 47.7 sec;
Measured values: 45.12 sec; 46.22 sec; 45.67 sec;
C 35/45, R_c = 48.7 N/mm^2
t_0=30 sec , k_1=1
Calculated values:
t_{m1}= 44.7sec
t_{m2}= 31.6 sec
Measured value: 30.45 sec

1.5 cm

C 25/30**,** R_c = 41.5 N/mm^2**;** C 30/37 **,** R_c = 46.8 N/mm^2
t_0=30 sec
t_m recommended by the mixer manufacturer 40 sec
Calculated values:
t_{m1}= 41 sec; 42.8 sec;
t_{m2}= 32 sec; 32 sec;
Measured values: 30.22 sec; 31.15 sec;

C 25/30**,** R_c = 45.8 N/mm^2
t_m recommended by the mixer manufacturer 40 sec
t_0=45 sec
t_{m1}= 62 sec
t_{m2}= 48.05sec
Measured value: 46.14 sec

2.0 cm

C 12/15, R_c = 19.6 N/mm^2 ; C 16/20**,** R_c = 27.3 N/mm^2**;** C 18/22,5**,** R_c = 26.4 N/mm^2 ;
C 25/30**,** R_c = 38.2 N/mm^2
t_0=30 sec
t_m recommended by the mixer manufacturer 40 sec
Calculated values:
t_{m1}= 32.7 sec; 34.6 sec; 35.6 sec; 39.4 sec;
t_{m2}= 30.8 sec; 31.1 sec; 31.1 sec; 31.9 sec;
Measured values: 31.34 sec; 31.18 sec; 30.92 sec; 32.14 sec.

Mixing time variation with compresion strength on cubes , for mixer with vertical axis with capacities of 0.5 cm, 1.0 cm and 2.0 cm, at concrete preparation of resistance classes C 12/15 - C 35/45

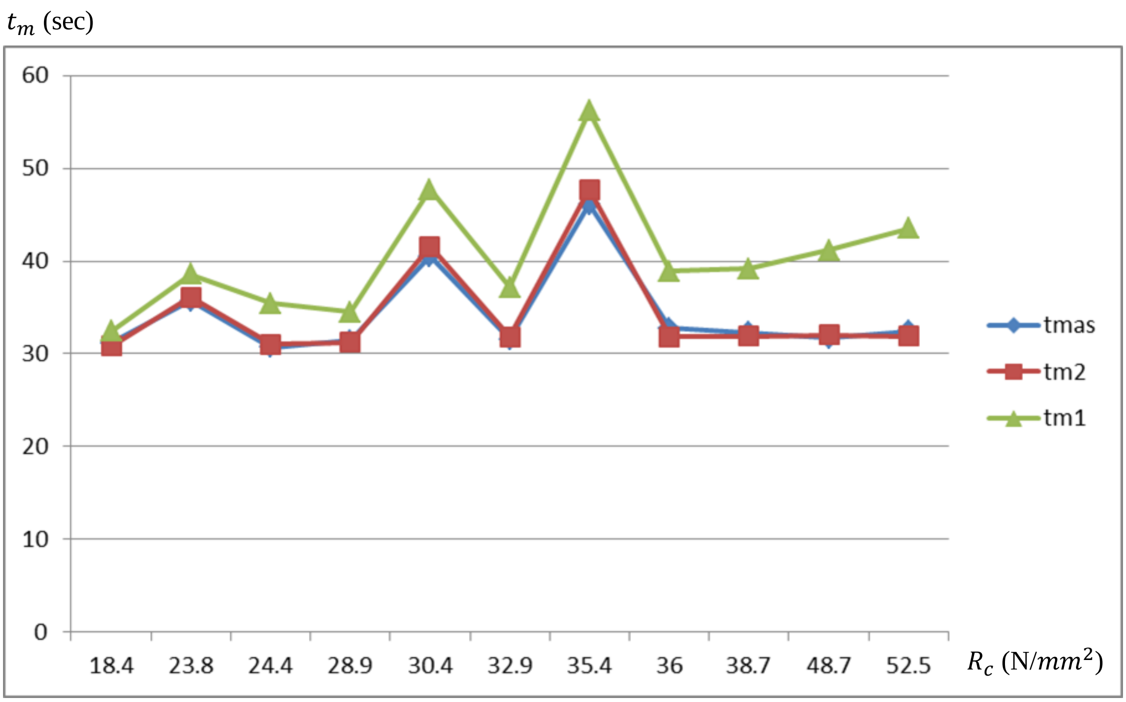


Figure 12

t_{mas} is mixing time determined by directly measurement with the stopwatch at a concrete batch preparation;

t_{m2} is mixing time determined by calculation,with relation (10), in which :
- k_1=1, for all analyzed cases;
- f_m=0, the mixer influence is not available, k_2= k_r;
- f_r is determined with relation (13) , in which ρ_x, ρ_{x-1} , reprezent the densities of the mixture from mixer for concrete class X and for the previous one X-1 , and the reports water/cement are introduced for X concrete class and the previous one X-1.

$t_{m1}$is mixing time determined by calculation, with relation (10), in which :
- k_1=1, for all cases analyzed;
- f_m are various values depends on by de mixer capacity;
- f_r is determined with relation (14) , in which ρ_x, ρ_0 , represent the densities of mixture from mixer for X concrete class and class C 8/10, and the reports water/cement are introduced for X concrete class and class C 8/10;

R_{c0}= 10 N/mm^2 (minimum reference resistance, for concrete class C 8/10.

Mixing time variation with compression strength on cubes, for mixers with two vertical axis, with capacities of 1.0 cm, 1.5 cm and 2.0 cm, at concrete preparation of resistance classes C 12/15- C 50/60

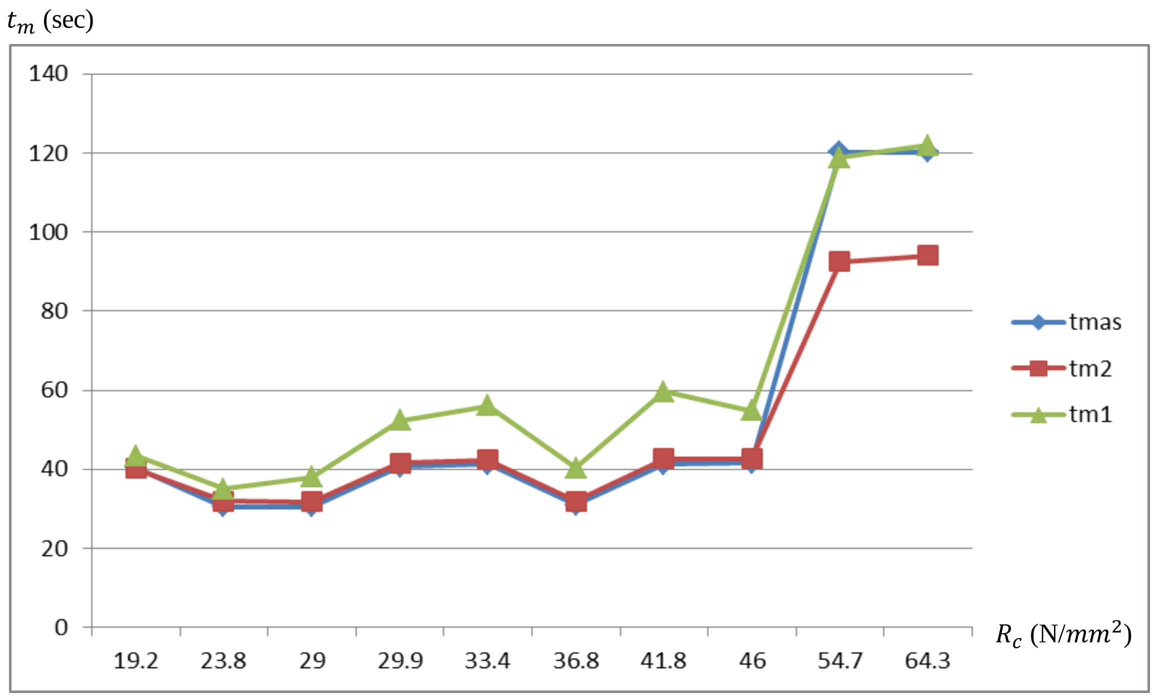


Figure 13

Mixing time variation with compression strength on cubes, for mixers with two horizontal axis , with capacities of 1.0 cm, 1.5 cm and 2.0 cm, at concrete preparation of resistance class C 12/15- C 35/45

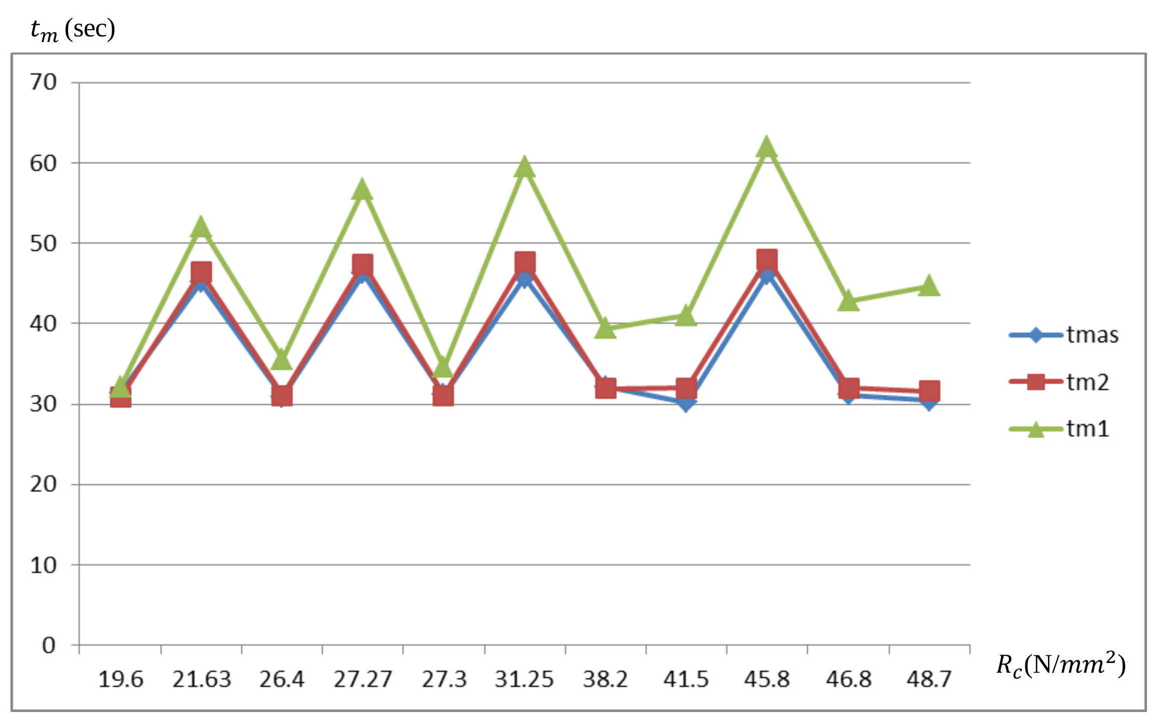


Figure 14

6. Conclusions

Analyzing the results obtained for the three mixing systems, represent in the graphs from figures 12, 13 and 14 we can synthesize the next conclusions :

1) The concrete stations equipped with one vertical axis mixers have respected the mixing time provided by the mixer manufaturer;

2) In the case of the stations equipped with two vertical or horizontal axis mixers, we found some cases in which the mixing time recommended by the mixer manufacturer was not respected;

3) In some cases the mixing time prescribed in the recipe exceeded the value recommended by the mixer manufacturer, providing the additional warranty to produce the quality concrete;

4) In the most cases, the measured values for mixing times and the calculated values for t_{m2} were very closed, the relation between mixing duration in relation to compression strength for t_{m2} highlighting the general working mode in concrete stations;

5) In the case of special concrete preparation of resistance classes C 40/50 and C 50/60 (the case of two vertical axis mixer of 2.0 cm) , k_1= 1.5 and in this case the measured values and those for t_{m2} (calculated) differ; in this case the proposed values t_{m1} are closed by the measured values;

6) In most analyzed cases, the values obtained for t_{m1}(like mixing time proposed) are higher than measured values and of those determined with relation t_{m2} , the biggest differences resulting in the case of compression strength determined in the laboratory with the biggest values; these values are getting close by those prescribed in table 1;

7) In the case of the values smaller of compression strength resulted in the laboratory the values for t_{m1} are getting pretty close by the measured values and those for t_{m2} , especially in the case of the resistance limit values, which leads to the conclusions that mixing times proposed for the version t_{m1}, can be applied in all concrete stations and especially at those stations where it was not taking into account the recommended mixing duration.

7. Optimum mixing time

From case to cases and from concrete class to another, the optimum mixing duration can be considered to be located in the range t_{min}, t_{max}, in which the minimum value corresponds to the recommended duration of mixer manufacturer , and the maximum value is t_{m1}.

MONITORING SYSTEMS OF THE TRUCK- MIXERS

REAL-TIME MONITORING

Fleet management and the drivers amanagement
– it is sent automatic report by email
– fuel consumption monitoring
– car navigation
– active driver on car
– cars use in personal interest
– documents expiration warnings: drive license, RCA, ITP, CASCO
– driving style of the drivers
– postions update at every 10s , car GPS location

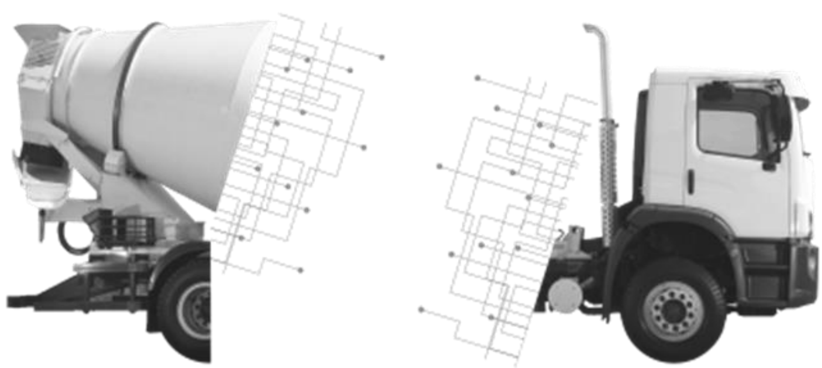
Other solutions

OBD – Diagnose on board

The device OBD (On Board Diagnostics) is a system connected to the car's electronic control panel, allowing the online reading and transmission of the most diverse types of mechanical and electronic vehicle navigation data of vehicles. Electronic diagnostics will notify you of scheduled repairs and reduce the need to go to a service center. In addition, it ensures that the vehicle operates at the parameters at which it was designed, which ensures savings and reduces wear on parts.

RFID (iButton) - driver identification

Identifying the driver via the RFID module (iButton) is identifying the driver by his badge or tag. As soon as the ignition is switched on, an audible alarm is sent to the driver to place his card on the RFID reader. The crawler sends this information instantly to the datacenter so that it can be queried immediately.



- Trucks / concrete mixers
- Having GPS on trucks, with the control module of the concrete mixer we can identify the direction of rotation, if it mixes the concrete, even when unloading the concrete, thus avoiding a diversion and an unnecessary delivery in an unwanted place. All this through real-time gps monitoring without human interference.
- Driving time
- Driving time is a solution that allows you to identify the driver and all the information about the race, identifying the start, end, driving hours, distance computer, fuel computer, fuel consumption monitoring, etc. This information is sent instantly to the server and is displayed in each report

Photo 1. Monitoring system of truck-mixers by GPS, at an automatic concrete station. The cars position is monitorized in real time on the map.

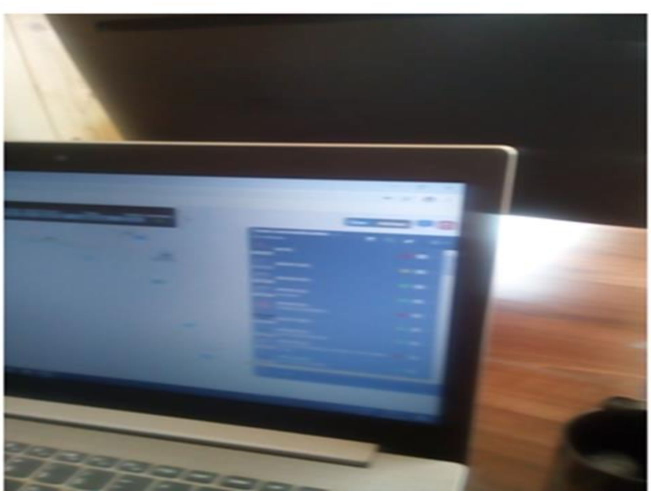


Photo 2. On the monitor can be displyed the track-mixers located on the route, with details concerning to the route taken and fuel consumption