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Considerații privind eliminarea deşeurilor biologice prin incinerare
Studiu de caz: stația de epurare a apelor uzate Oradea

Considerations for biological waste disposal by incineration
Case study: wastewater treatment Oradea station

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Rezumat: *Prin implementarea prevederilor legale în activitatea curentă a agenților economici şi a administrațiilor publice locale, se preconizează că impactul gestionării deşeurilor asupra mediului şi sănătății umane se va reduce semnificativ. Pentru îndeplinirea obiectivelor de mai sus este necesară implicarea practic a întregii societăți, reprezentată prin autorități publice, generatori de deşeuri, asociații profesionale, societatea civilă.*

Cuvinte cheie: deşeuri biologice, incinerare

Abstract: *By implementing legislation in the activity of economic agents and local government, it is expected that the impact of waste management on the environment and human health will be significantly reduced. To achieve the above objectives the need to involve virtually the entire society, represented by public authorities, waste generators, professional associations, civil society.*

Key words: biological waste, incineration

Incinerarea deşeurilor biologice. (Reglementări generale)

În prezent regimul deşeurilor este reglementat şi în România de Directiva 2006/12/CE a Parlamentului European şi a Consiliului din 5 aprilie 2006 privind deşeurile publicată în JO L 114, 27.4.2006, p. 9. Directiva 2006/12/CE este abrogată prin Directiva 2008/98/CE a Parlamentului European şi a Consiliului din 19 noiembrie 2008 privind deşeurile şi de abrogare a anumitor directive (JO L 312, 22.11.2008, p. 3) începând de la data de 12 decembrie 2010 şi Directiva 91/689/CEE a Consiliului din

12 decembrie 1991 privind deşeurile periculoase; Directiva 98/2008 va fi transpusă legislativ în anul 2010 şi de România.

Strategia Națională de Gestionare a Deşeurilor *(SNGD*)se bazează pe o nouă abordare a problematicii de gestionare a deşeurilor – **sistemul integrat de gestionare a deşeurilor** eficient din punct de vedere economic şi care să asigure protecția sănătății populației şi a mediului.

Noua abordare pune accent pe prima etapă a fluxului deşeurilor – prevenirea generării de deşeuri, urmată în ordine, de reutilizare reciclare,valorificare

energetică şi, în final, depozitare. Principalele instrumente de realizare sunt:

- Prevenirea şi minimizarea
- Reciclarea şi valorificarea
- Colectarea separată a anumitor tipuri de deşeuri
- Dezvoltarea serviciilor de colectare şi transport a deşeurilor la instalațiile autorizate pentru tratare şi/sau valorificare materială prin reciclare şi energetică prin incinerare / co-incinerare cu recuperare de energie) eliminare (prin incinerare sau depozitare în depozite speciale).

Prin respectarea prevederilor legale în activitatea curentă a agenților economici şi a administrațiilor publice locale, se preconizează că impactul gestionării deşeurilor asupra mediului şi sănătății umane se va reduce semnificativ.

Pentru reuşita îndeplinirii obiectivelor de mai sus este necesară practic, implicarea întregii societăți, reprezentată prin autorități publice, generatori de deşeuri, asociații profesionale, societatea civilă.

În negocierile de aderare la U.E, România a transpus în totalitate *acquis-ul comunitar* privind *gestionarea deşeurilor* şi şi-a asumat implementarea acestuia până la data aderării, cu excepția următoarelor domenii pentru care a solicitat şi obținut perioade de tranziție:

- ambalajele şi deşeurile de ambalaje;
- depozitarea deşeurilor;
- incinerarea deşeurilor;
- deşeurile de echipamente electrice şi electronice;
- importul, exportul şi tranzitul de deşeuri.

Elaborarea unei strategii la nivel național şi identificarea măsurilor şi a acțiunilor de implementare a acestei strategii prin planul național de gestionare a deşeurilor şi planurile regionale, județene şi locale a fost impusă prin implementarea acquis-ul.

Strategia Națională de Gestionare a Deşeurilor (SNGD) a stabilit obiective pentru toate tipurile de deşeuri cum ar fi: obiective generale pentru gestionarea deşeurilor şi obiective specifice pentru gestionarea unor fluxuri speciale de deşeuri.

Programul Național de Gestionare a Deşeurilor (*PNGD) a stabilit obiective, măsuri şi acțiuni privind* prevenirea sau reducerea producerii de deşeuri şi a gradului de periculozitate al acestora prin:

- Implementarea de tehnologii curate, cu consum redus de resurse naturale;
- Încurajarea şi dezvoltarea de tehnologii noi, şi comercializarea de produse care prin modul de fabricare, utilizare sau eliminare nu au impact sau au cel mai mic

impact posibil asupra creşterii volumului sau periculozității deşeurilor ori asupra riscului de poluare;

• Promovarea de tehnologii adecvate pentru eliminarea finală a substanțelor periculoase din deşeurile destinate valorificării;

• Valorificarea deşeurilor prin reciclare, reutilizarea şi recuperarea acestora, sau orice alt proces prin care se obțin materii prime secundare ori utilizarea deşeurilor ca sursă de energie.

România trebuie să informeze Comisia Europeană conform procedurilor comunitare stabilite pentru furnizarea de informații, cu privire la măsurile luate pentru atingerea obiectivelor stabilite la aliniatele prezentate mai sus.

Fig. 1 Chesonul de depozitare a grăsimilor provenite din Separatorul de grăsimi

Necesitatea incinerării deşeurilor biologice provenite de la Stația de Epurare Apelor Uzate Oradea.

Problema deşeurilor provenite de la Stația de Epurare a Apelor Uzate Oradea este deocamdată nerezolvată. Dacă pentru deşeurile reținute de grătare în treapta mecanică există posibilitatea transportului la depozitul municipal, pentru deşeurile reținute de separatorul de grăsimi în mare parte uleiuri auto, detergenți şi grăsimi de origine animală problema este mai gravă deoarece fac parte din categoria deşeurilor biologice periculoase iar la ora actuală singura rezolvare este depozitarea lor în chesonul special amenajat în imediata apropiere a separatorului de grăsimi această soluție fiind o rezolvare temporară.

Având în vedere acest aspect, propunem două soluții care pot fi luate în considerare şi anume:

• Prima soluție ar fi transportul acestor deşeuri la fabrica Holcim Chistag care se află la aproximativ 40 de km de stația de epurare unde funcționează o instalație de condiționare, a deşeurilor combustibile lichide şi solide, periculoase şi nepericuloase, necesare co-incinerării în cuptorul de clincher de ciment. Pentru a se putea realiza acest procedeu, deşeul biologic trebuie transformat din starea vâscoasă pe care o are la colectare, într-o formă mai uscată, eventual amestecarea lui cu nămol dezhidratat provenit de la centrifugile de dezhidratare. Această operaţie, necesită echipamente speciale şi resurse financiare pentru efectuarea transportului până la incinerator.

De menţionat că în cuptorul de clincher s-ar realizeaza inclusiv valorificarea termoenergetică a deşeurilor de ambalaje co-incinerabile improprii pentru reciclare sau reutilizare.

Instalaţia de co-incinerare figurează ca alternativă la depozitarea deşeurilor combustibile sortate şi face parte dintre fluxurile necesare reducerii cantităţii de deşeuri depozitate definitiv.

- A doua soluţie şi cea mai viabilă, presupune achiziţionarea unui incinerator care să fie amplasat în interiorul staţiei, cu posibilitatea să fie racordat la reţeaua de biogaz produs în staţia de epurare, reducând astfel costurile. Totodată, ar da posibilitatea prestării de servicii de neutralizare a deşeurilor periculoase produse de agenţii economici (spitale, frizerii, farmacii etc.) de pe raza judeţului Bihor, realizând astfel un venit suplimentar la bugetul companiei.

Având în vedere faptul că masa de deşeuri biologice este de aproximativ 20-30 kg/zi, propunem achiziţionarea unui incinerator ecologic de tip IE50 cu următoarele caracteristici:

- cantitate de incinerare /şarjă: 50-150 kg
- cantitatea incinerată în 24h: 600 kg
- durată unei şarje: 2h
- dimensiunile camerei primare: lungime 1200 mm
lăţime 1100 mm
înălţime 1200 mm
- debitul de biogaz: 58Nm^3/h
- puterea electrică: 380V/50Hz
- dimensiune gabarit exterior: lungime 4500 mm
lăţime 2900 mm
înălţime 2400 mm

- posibilitatea de alimentare: manual sau mecanizat;
- posibilitatea de a se anexa un recuperator de căldură;
- posibilitatea de a se anexa o instalaţie de spălare şi filtrare a gazelor.

Costul unui astfel de incinerator este de 20 mii € plus 5 mii € racordul şi coşul de fum iar instalarea de către o firmă specializată în domeniu ar fi aproximativ 4 mii€, deci în total, ar fi o investiţie de 29.000 €.

Recuperarea acestei investiţii se va face relativ rapid, în aproximativ doi până la trei ani, prin prestarea de servicii contra cost agenţilor economici zonali din a căror activitate rezultă deşeuri periculoase ce trebuiesc neutralizare prin incinerare, rezolvând totodată şi problema deşeurilor biologice din staţia de epurare.

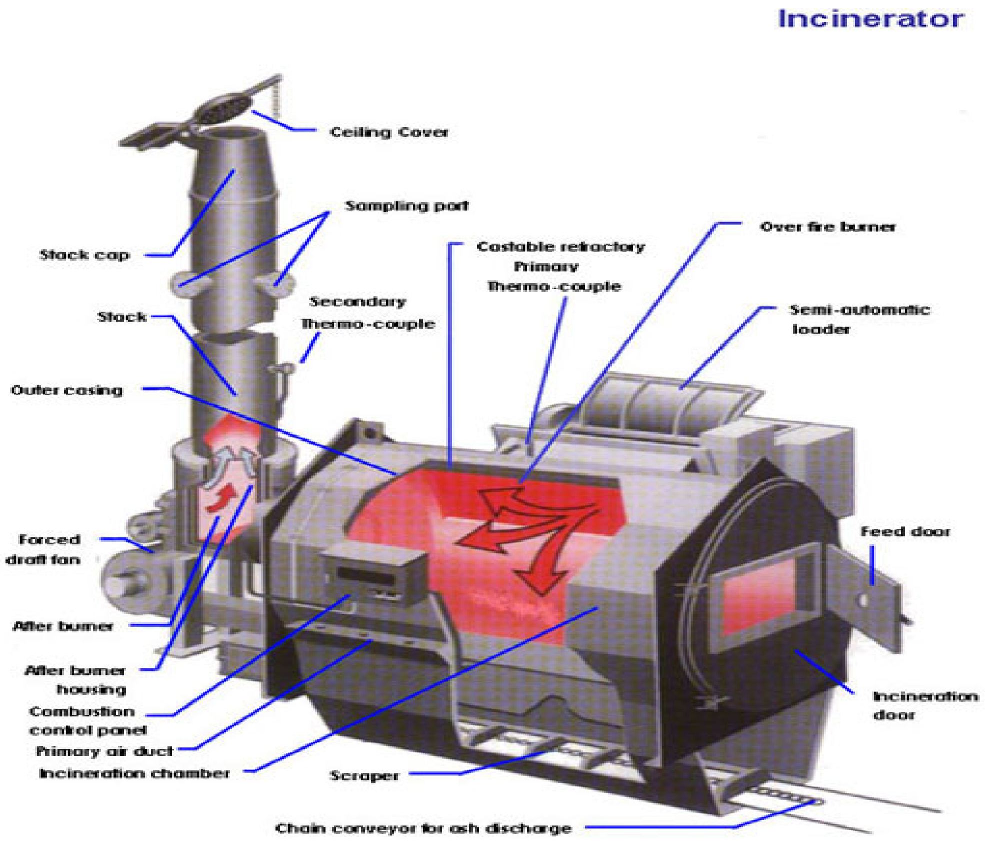

Fig. 2 Incinerator ecologic de tip IE50

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Cercetari experimentale privind utilizarea adaosurilor de zgura granulata de furnal in beton. Determinarea experimentala a valorii coeficientului k. Partea 1

Experimental research on the use of granulated blast furnace slag additives in concrete. Experimental determination of the k coefficient value. Part 1

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Rezumat: *In aceasta lucrare se prezinta baza teoretica si determinarile experimentale desfasurate la UTCB in vederea determinarii coeficientului k, care indica contributia adaosurilor de zgura din betoane pentru obtinerea unei rezistente echivalente cu cea a unui beton fara adaosuri. Aceasta reprezinta o prima etapa importanta care trebuie parcursa in conformitate cu abordarile moderne privind stabilirea performantelor echivalente ale betonului in cazul utilizarii adaosurilor in beton.*

Cuvinte cheie: beton, adaos, zgura, coeficient k,

Abstract: *This paper presents the theoretical and experimental determinations performed in UTCB to determine the coefficient k, which indicates the contribution of slag additives in concrete to achieve an equivalent strength to that of concrete without additives. This is an important first step that must be covered in accordance with the modern approach to establish equivalent performance of concrete with additives.*

Key words: concrete, additive, slag, k coefficient

1. Introducere

Prezenta lucrare a avut ca obiectiv principal studiul comportarii betoanelor preparate cu diferite procente de zgura, din punct de vedere al rezistentei la compresiune si compararea valorilor rezistentelor cu cele obtinute pentru betoane preparate fara adaosuri de zgura, in vederea determinarii experimentale a valorii coeficientului k.

Determinarea valorii coeficientului k reprezinta o etapa esentiala in abordarile moderne privind performantele echivalente ale betonului in cazul utilizarii unor adaosuri in betoane.

Rezultatele prezentate in lucrare reprezinta o prima etapa in realizarea cercetarilor experimentale privind durabilitatea betoanelor cu adaosuri de zgura comparativ cu durabilitatea betoanelor preparate cu cimenturi cu adaosuri de zgura, continand aproximativ aceeasi proportie de adaosuri, rezultate care vor fi prezentate in partea a doua a articolului.

2. Consideratii teoretice privind determinarea valorii coeficientului k

In propunerea privind revizuirea standardului european EN 206-1 [1], in cazul utilizarii zgurii ca adaos in beton, se propune o valoare a factorului k=0,6, in cazul in care zgura se conformeaza standardului EN 15167-1 [2].

In propunerea de revizuire se mai prezinta precizari legate de raportul maxim masic intre zgura si ciment si anume: $\frac{zgura}{ciment} \leq 1{,}0$.

In cazul in care se va utiliza o cantitate mai mare de zgura, nu va fi luata in considerare la calculul raportului Apa/ (ciment + k • zgura).

De asemenea, in propunerea de revizuire a standardului se mentioneaza necesitatea aplicarii conceptului echivalent de performanta in vederea stabilirii unor cerinte de compozitie pentru cimenturi sau betoane cu adaosuri care sa asigure performante echivalente cu ale unor compozitii de betoane preparate cu cimenturi cu o buna comportare in medii echivalente.

Principiile privind modul de determinare a coeficientului k au fost elaborate inca din anul 1967 [3], iar in anul 2011 CEN/TC 104/SC1 N717 [4] a elaborat un raport privind utilizarea adaosurilor, in care se detaliaza acest principiu, prezentand exemple de aplicare la nivel european.

Adaosurile influenteaza in multe directii caracteristicile betonului proaspat si intarit, prima caracteristica care trebuie luata in considerare fiind rezistenta la compresiune a betonului la 28 de zile.

In betoanele ce au in compozitie adaosuri, raportul A/C este inlocuit cu raportul A/ (c +k • a),

unde k = coeficientul de echivalenta

a = adaosul din beton.

Factorul k indica contributia adaosurilor din betoane pentru obtinerea unei rezistente echivalente cu cea a unui beton fara adaosuri.

Utilizand notatiile din documentul european putem scrie relatia:

$$\omega_o = w_a/(c_a + k \cdot a) \qquad (1)$$

unde:

ω_o= raportul apa/ciment al betonului de referinta fara adaosuri

w_a = cantitatea de apa a betonului cu adaosuri (kg/m^3)

c_a = cantitatea de ciment a betonului cu adaosuri (kg/m^3)

a = cantitatea de adaosuri (kg/m^3)

In cazul in care acesti paramentri au fost determinati pentru o aceeasi rezistenta, coeficientul k poate fi calculat cu formula:

$$k = (w_a/\omega_o - c_a) / a \qquad (2)$$

sau normalizand cu cantitatea de ciment c_a din betonul cu adaosuri.

$k = (\omega_a / \omega_o - 1) / (a / c_a)$(3)

unde $\omega_a = w_a/c_a$ este raportul apa/ciment al betonului cu adaosuri.

In metodele descriptive de proiectare a compozitiei betonului, valoarea constantei k are semnificatia unei valori maxime, care poate fi utilizata pentru a dovedi ca raportul apa/ (ciment +k • adaos) al betonului nu depaseste raportul maxim apa/ciment, asa cum este definit pentru betonul fara adaosuri, in functie de o anumita clasa de expunere.

Prin aceasta nu se dau insa informatii privind performantele "echivalente" ale betonului preparat cu adaos fata de betonul fara adaosuri.

Determinarea valorii coeficientului k se bazeaza pe compararea performantelor unui beton de referinta preparat cu un ciment A cu un beton in care o parte din cimentul A a fost inlocuit cu un adaos, in functie de raportul A/C si de cantitatea de adaos.

Principiul de calcul se bazeaza pe relatia care exista intre raportul A/C si rezistenta betonului. Se prefera ca determinarile sa se efectueze pe mai multe compozitii de beton, deoarece aceasta sporeste precizia metodei. In general se prefera o relatie liniara care sa descrie dependenta dintre raportul A/C si rezistenta betonului.

Rezistenta la compresiune = a - b • apa/ciment

a; b – coeficienti

sau

$f_o = A_0 - B_0\,\omega_0$ (4) pentru betonul de referinta

$f_a = A_a - B_a\,(w/c+a)$ (5) pentru betonul cu adaosuri cu raportul a/c

Pe baza rezultatelor cercetarilor experimentale se determina valorile coeficientilor A_0, A_a, B_0, B_a pentru diferite rapoarte intre ciment si adaosuri c/a.

In cadrul cercetarilor efectuate pentru aceasta lucrare au fost utilizate rapoartele:

- a/c = 0,11 cu 10% zgura
- a/c = 0,587 cu 37% zgura.

Dupa determinarea valorii coeficientilor se efectueaza egalitatea relatiilor:

$f_{0\ (referinta)} = f_{a\ (adaos)}$

$f_0=f_a \Rightarrow A_0 - B_0\,\omega_o = A_a - B_a \bullet w / (c+a)$

$\omega_0 = w/ (c+k \bullet a) \Rightarrow w = \omega_0\,(c+k \bullet a)$

$\Rightarrow A_0 - B_0\,\omega_0 = A_a - B_a\,\omega_0\,(c+k \bullet a)/ (c+a)$

sau

$A_0 - B_0\,\omega_o = A_a - B_a\omega_o\,(1+k \bullet a/c)/ (1+a/c)$

Astfel, se poate determina valoarea coeficientului k, care nu va avea o valoare unica ci va fi in functie de raportul apa/ciment al betonului de referinta. Se va utiliza relatia:

$$k = \frac{(A_a - A_0)(1 + a/c)}{B_a \text{ x } a/c} \text{ x } \frac{1}{\omega_0} + \left[\frac{B_0(1 + a/c)}{B_a} - 1\right] \text{x } \frac{1}{a/c} \quad (6)$$

notatii utilizate:

ω_0 – raportul apa/ciment al betonului de referinta fara adaosuri;

ω_a - raportul apa/ciment al betonului cu adaosuri, $\omega_a = w_a/c_a$

w_a – cantitatea de apa a betonului cu adaosuri (kg/m^3)

c_a - cantitatea de ciment in betoanele cu adaosuri (kg/m^3)

a - cantitatea de adaosuri (kg/m^3)

f_a, f_0 - rezistentele la compresiune ale betonului (MPa)

$A_{0,}$ A_a, B_0, B_a – coeficienti ai relatiei liniare intre rapoartele A/C si rezistenta la compresiune a betonului pentru betonul de referinta si betonul cu adaosuri.

3.Rezultatele cercetarilor experimentale

Cercetarile exprimentale au constat in determinarea rezistentelor la compresiune, la diferite termene, a unor betoane preparate numai cu ciment de tip CEM I 42,5R si respectiv cu betoane cu CEM I 42,5R si adaosuri de zgura.

Betoanele au fost preparate pentru diferite dozaje de ciment si respectiv ciment si adaosuri de zgura 10% si respectiv 37%), aditiv superplastifiant, dozaj 1% din cantitatea de liant.

Rezultatele au fost utilizate pentru determinarea valorii coeficientului k.

In tabelele 1, 2 si 3 se prezinta compozitiile de beton utilizate. Mentionam ca pentru cele trei categorii de amestecuri s-au utilizat cantitati egale de liant, L (ciment, ciment plus 10% zgura si ciment plus 37% zgura).

Tabel 1

Compozitiile betoanelor preparate cu CEM I 42,5R

Ciment (kg/m^3)	Apa (l)	Aditiv (l)	Agregate (kg)	sort 0-4 mm	sort 4-8 mm	sort 8-16 mm
270	170.83	2.55	1893.43	757.37	378.69	757.37
300	159.33	2.83	1854.97	741.99	370.99	741.99
340	154.33	3.21	1801.10	720.44	360.22	720.44
370	158.33	3.49	1779.94	711.98	355.99	711.98
430	166.67	4.06	1704.35	681.74	340.87	681.74

Tabel 2

Compozitiile betoanelor preparate cu CEM I 42,5R si 10% zgura

Ciment (kg/m^3)	Zgura (kg/m^3)	Apa (l)	Aditiv (l)	Agregate (kg)	sort 0-4 mm	sort 4-8 mm	sort 8-16 mm
243	27	160.00	2.55	1893.43	757.37	378.69	757.37
270	30	156.00	2.83	1854.97	741.99	370.99	741.99
306	34	143.33	3.21	1801.10	720.44	360.22	720.44
333	37	152.50	3.49	1779.94	711.98	355.99	711.98
387	43	153.33	4.06	1704.35	681.74	340.87	681.74

Tabel 3

Compozitiile betoanelor preparate cu CEM I 42,5R si 37% zgura

Ciment (kg/m^3)	Zgura (kg/m^3)	Apa (l)	Aditiv (l)	Agregate (kg)	sort 0-4 mm	sort 4-8 mm	sort 8-16 mm
170.10	99.90	156.67	2.55	1893.43	757.37	378.69	757.37
189.00	111.00	146.00	2.83	1854.97	741.99	370.99	741.99
214.20	125.80	141.67	3.21	1801.10	720.44	360.22	720.44
233.10	136.90	150.00	3.49	1779.94	711.98	355.99	711.98
270.90	159.10	147.67	4.06	1704.35	681.74	340.87	681.74

Rezultatele obtinute pentru caracteristicile betoanelor proaspete sunt prezentate in tabelele 4 - 6.

Tabel 4

Caracteristicile betoanelor proaspete preparate cu CEM I 42,5R

Ciment (kg/m^3)	A/L	Tasare (mm)	Densitate (kg/m^3)
270	0.64	150	2379
300	0.54	150	2405
340	0.46	150	2439
370	0.44	150	2400
430	0.40	150	2433

Tabel 5

Caracteristicile betoanelor proaspete preparate cu CEM I 42,5R si 10% zgura

Ciment (kg/m^3)	Zgura (kg/m^3)	A/L	Tasare (mm)	Densitate (kg/m^3)	Observatii
243	27	0.60	110	2398	Beton necoeziv
270	30	0.53	135	2424	Beton necoeziv
306	34	0.43	125	2446	-
333	37	0.42	145	2414	-
387	43	0.37	105	2418	-

Tabel 6

Caracteristicile betoanelor proaspete preparate cu CEM I 42,5R si 37% zgura

Ciment (kg/m^3)	Zgura (kg/m^3)	A/L	Tasare (mm)	Densitate (kg/m^3)	Observatii
170.10	99.90	0.59	120	2424	Beton necoeziv, Separare apa
189.00	111.00	0.50	150	2420	Beton necoeziv, Separare apa
214.20	125.80	0.43	145	2445	Beton necoeziv
233.10	136.90	0.41	150	2421	-
270.90	159.10	0.35	145	2443	-

In tabelele 7 - 9 se prezinta rezistentele la compresiune la 2, 7 si 28 de zile obtinute pentru cele 3 variante de amestecuri.

Tabel 7

Caracteristicile de rezistenta ale betoanelor intarite preparate cu CEM I 42,5R

Dozaj ciment (kg/m^3)	A/L	Rezistenta la compresiune (N/mm^2)					
		2 zile		7 zile		28 zile	
270	0.64	20.24	19.96	33.66	31.92	36.62	36.85
		20.00		30.47		36.41	
		19.65		31.64		37.52	
300	0.54	27.72	27.51	40.91	41.66	48.18	48.51
		26.96		42.14		48.38	
		27.85		41.93		48.96	
340	0.46	37.00	36.55	49.79	48.86	51.55	54.72
		36.28		48.44		56.66	
		36.38		48.34		55.94	
370	0.44	40.24	40.96	48.54	50.15	56.25	55.74
		41.46		51.47		56.66	
		41.18		50.45		54.31	
430	0.40	45.27	45.32	52.18	51.12	61.61	61.90
		46.78		50.84		61.63	
		43.90		50.33		62.46	

Tabel 8

Caracteristicile de rezistenta ale betoanelor intarite preparate cu CEM I 42,5R si 10% zgura

Dozaj zgura (kg/m^3)	Dozaj ciment (kg/m^3)	A/L	Rezistenta la compresiune (N/mm^2)					
			2 zile		7 zile		28 zile	
27	243	0.60	19.56	19.62	31.15	30.93	38.44	37.81
			19.44		30.42		38.01	
			19.87		31.22		36.99	
30	270	0.53	27.94	27.81	39.00	39.77	44.88	46.12
			27.61		40.09		48.33	
			27.89		40.22		45.14	
34	306	0.43	36.07	36.69	47.25	48.40	58.52	56.45
			36.47		49.62		56.39	
			37.53		48.33		54.44	
37	333	0.42	38.46	39.31	52.47	50.34	57.16	58.70
			40.36		50.33		59.52	
			39.11		48.21		59.41	
43	387	0.37	42.06	43.16	55.35	55.15	60.24	60.39
			42.32		54.88		59.37	
			45.11		55.22		61.57	

Tabel 9

Caracteristicile de rezistenta ale betoanelor intarite preparate cu CEM I 42,5R si 37% zgura

Dozaj zgura (kg/m³)	Dozaj ciment (kg/m³)	A/L	Rezistenta la compresiune (N/mm²)					
			2 zile		2 zile		2 zile	
99.9	170.1	0.59	11.93	12.30	22.13	21.66	31.38	30.62
			12.79		21.52		29.51	
			12.17		21.34		30.98	
111.0	189.0	0.50	17.13	17.25	31.74	31.97	43.61	43.27
			17.80		31.78		41.58	
			16.82		32.39		44.63	
125.8	214.2	0.43	22.33	22.67	38.60	39.72	54.63	52.77
			22.84		40.44		52.80	
			22.84		40.11		50.88	
136.9	233.1	0.41	24.05	24.32	42.43	43.53	54.75	54.89
			24.87		44.89		54.61	
			24.03		43.27		55.31	
159.1	270.9	0.35	30.96	31.45	50.84	49.98	56.84	57.67
			31.75		48.76		58.20	
			31.64		50.33		57.98	

Pe baza acestor rezultate s-au trasat diagramele rezistenta la compresiune la 2, 7 si 28 de zile in functie de raportul apa/ liant (fig. 1...3) si respectiv dependenta rezistentei la compresiune la varsta de 28 de zile in functie de raportul apa/ liant (fig. 4...6).

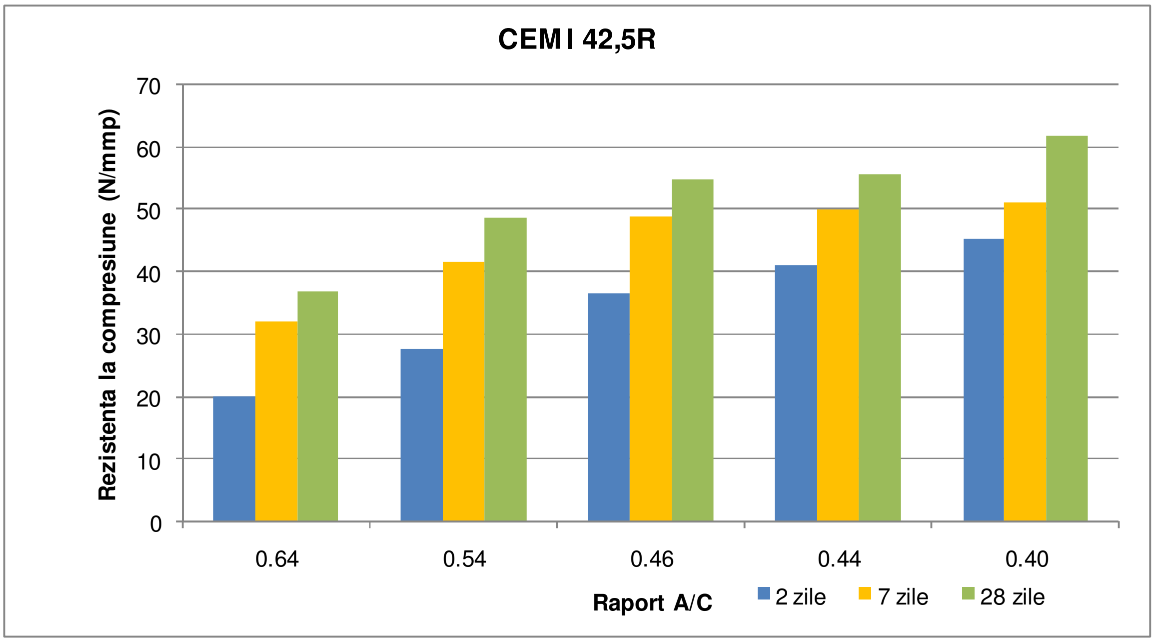

Fig. 1 – Rezistenta la compresiune a betoanelor preparate cu CEM I 42,5R

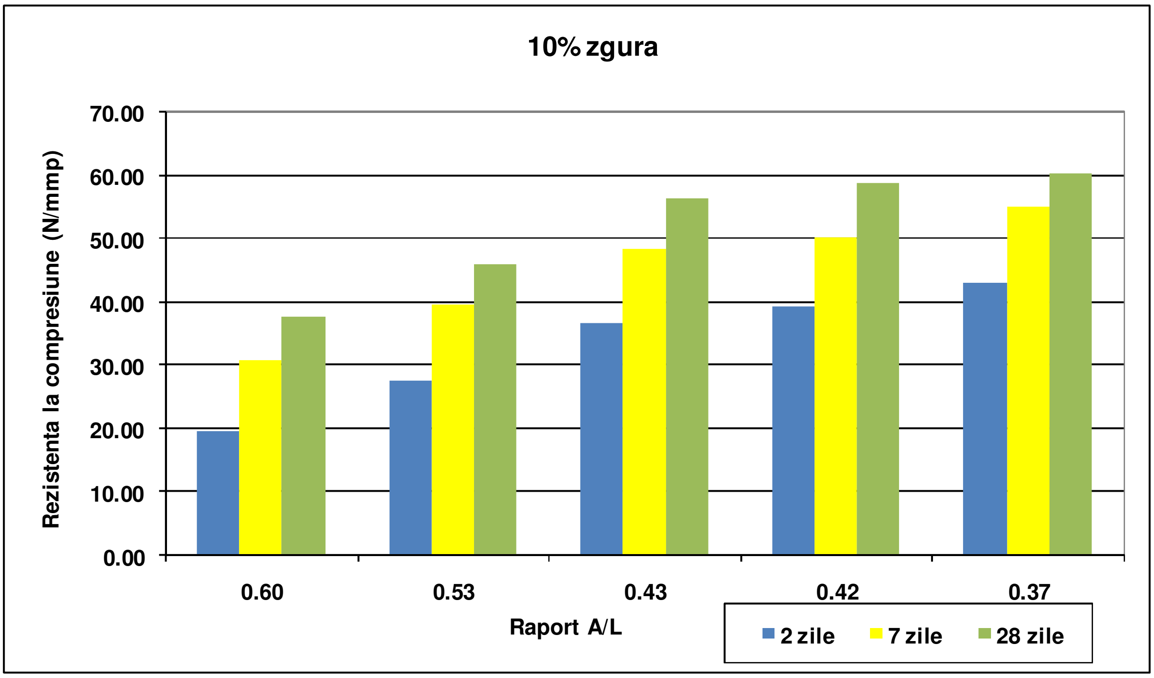

Fig. 2 – Rezistenta la compresiune a betoanelor preparate cu CEM I 42,5R si 10% zgura

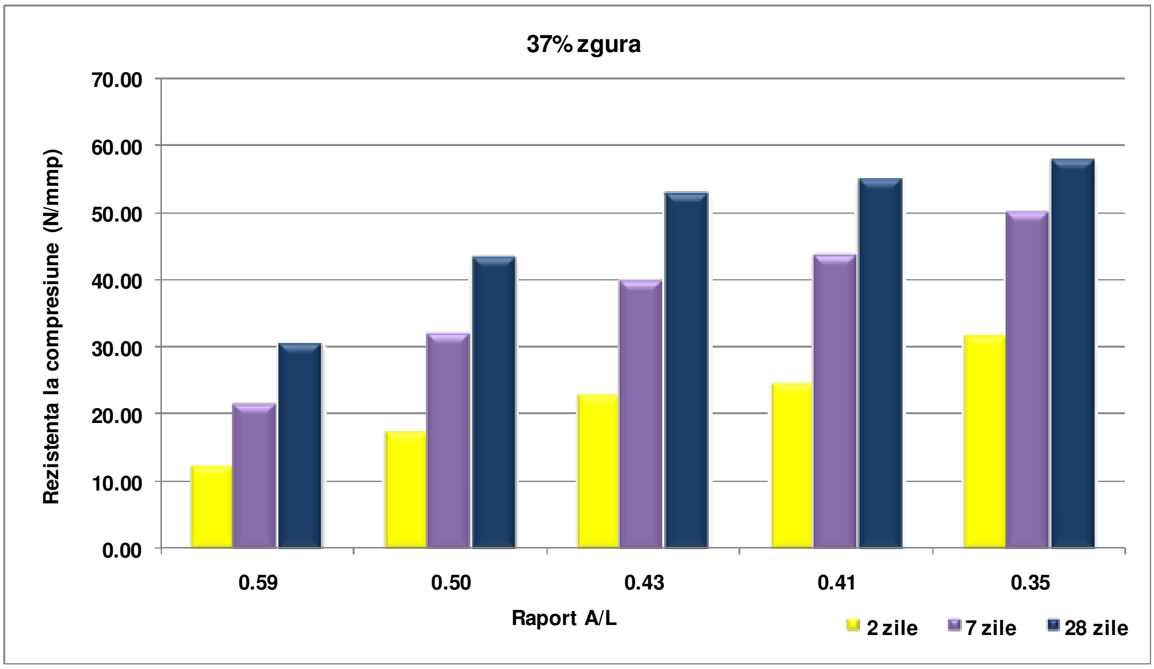

Fig. 3 – Rezistenta la compresiune a betoanelor preparate cu CEM I 42,5R si 37% zgura

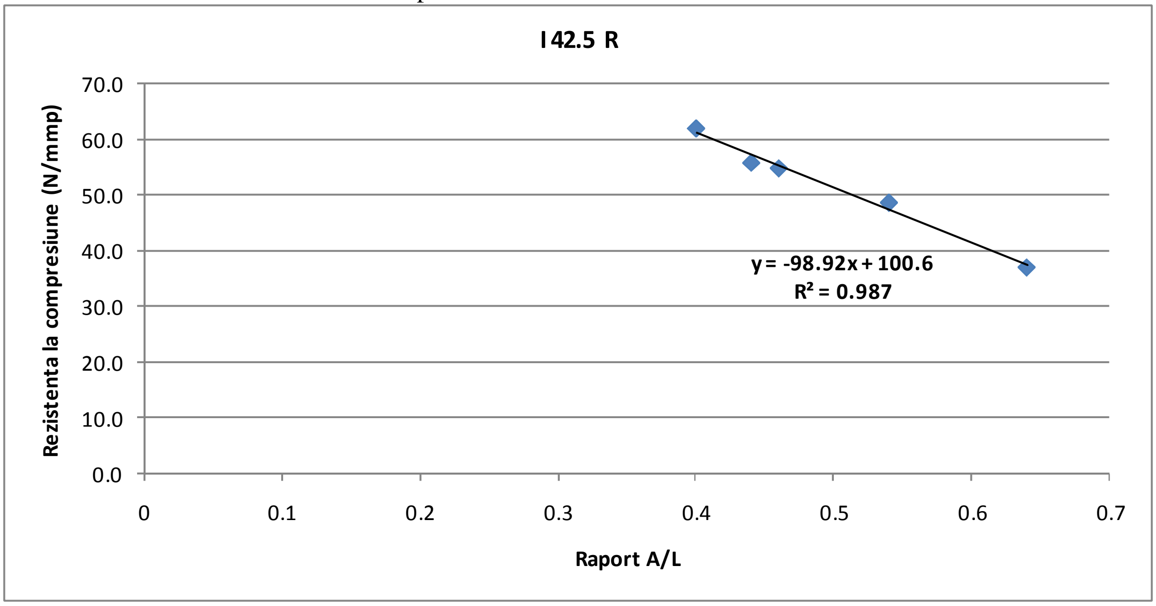

Fig. 4 – Rezistenta la compresiune la 28 de zile a betoanelor preparate cu CEM I 42,5R

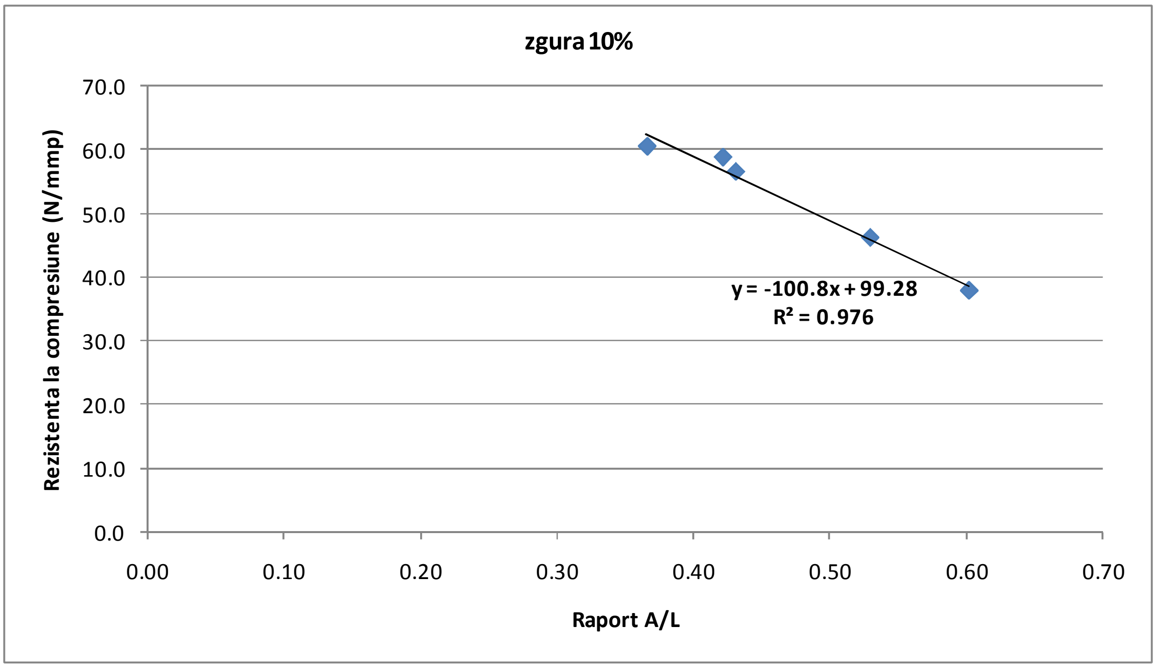

Fig. 5 – Rezistenta la compresiune la 28 de zile a betoanelor preparate cu CEM I 42,5R si 10% zgura

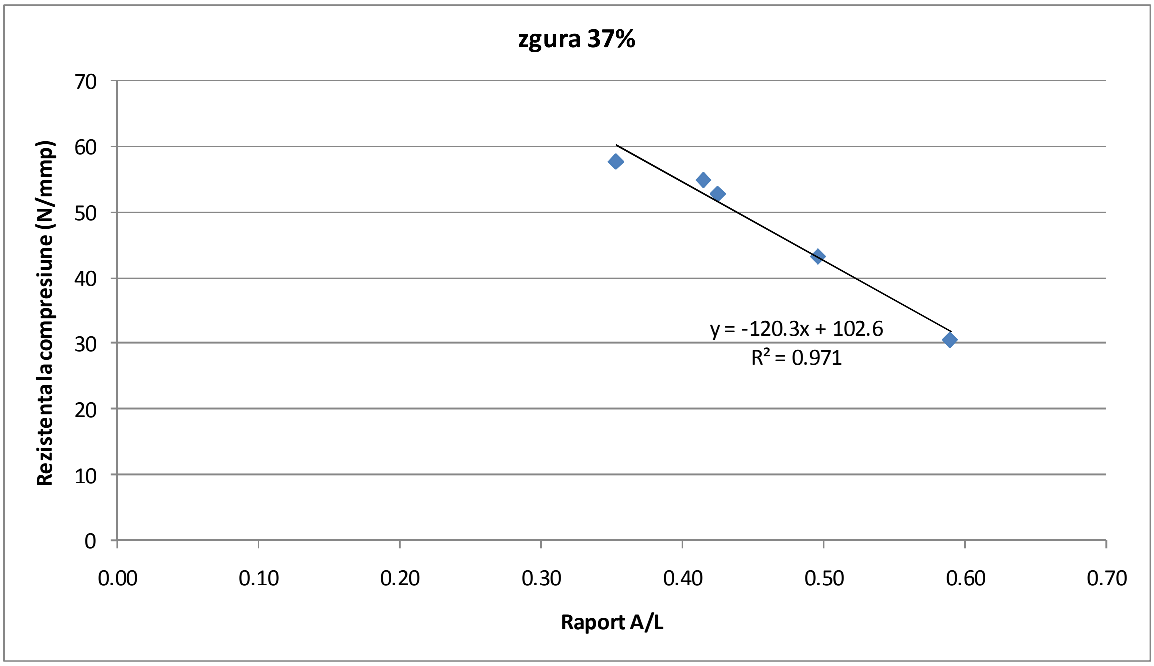

Fig. 6 – Rezistenta la compresiune la 28 de zile a betoanelor preparate cu CEM I 42,5R si 37% zgura

Diagramele prezentate in fig. 4, 5 si 6 au fost utilizate pentru determinarea coeficientilor A_0, B_0 pentru betonul de referinta si respectiv A_a si B_a pentru cele doua tipuri de betoane avand proportii diferite de adaosuri.

S-au obtinut urmatoarele rezultate:

$f_0 = 100{,}6-98{,}92\ \omega_0$

$f_a = 99{,}28-100{,}8$ w/(c+a) (10% zgura)

$f_a = 102{,}6-120{,}3$ w/(c+a) (37% zgura)

Aplicand relatia (6) obtinem, pentru betonul cu adaos de zgura 10%, relatia:

$k=-0{,}132/\ \omega_0 + 0{,}812$ (7)

iar pentru betonul cu adaos de zgura 37%:

$k= 0{,}0473/\ \omega_0 + 0{,}524$ (8)

Aplicand relatiile (7) si (8) pentru diferite rapoarte apa /ciment ω_0=0,45; 0,5; 0,60, 0,65, pentru ambele procente de adaosuri s-a obtinut o valoare minima acoperitoare a coeficientului k de 0,5, valorile variind intre 0,52 si 0,62.

4. Concluzii

Betoanele in stare proaspata preparate cu dozaje mai reduse de ciment si adaosuri de zgura prezinta un aspect necoeziv.

Rezultatele inregistrate si prelucrarile efectuate conduc la concluzia ca, pentru tipurile de materiale utilizate, este indicata o valoare a factorului k egala cu 0,5.

Determinarea valorii coeficientului k reprezinta o etapa esentiala in abordarile moderne privind performantele echivalente ale betonului in cazul utilizarii unor adaosuri in betoane.

Pe baza acestor rezultate se poate trece la o alta etapa de cercetare care trebuie sa aiba drept scop determinarea si compararea valorilor unor caracteristici de durabilitate a betoanelor preparate cu cimenturi cu adaosuri de zgura si respectiv cu betoane cu adaosuri de zgura utilizand aceleasi procente de adaosuri, adica stabilirea performantelor echivalente.

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Usage Mobile Phone for Pavement Distresses Measurement in Irbid city – Jordan

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Abstract: *The main objective of this research work was to investigate the potential using camera of mobile phone system as one of the most common techniques for spatial distribution studies. This study aims to use mobile camera phone in different locations of Irbid city, it was very easy to located alligator cracking and longitudinal & transverse cracking for different locations in Irbid city as an attempt to investigate cracks quantities using automated validated process to help non-experienced people to perform a distress generation.*

Keywords: Pavement distresses, Alligator cracking, Longitudinal and transverse cracking.

Literature Review

In the past, pavement were maintained but not managed. The pavement engineer's experience tended to indicate the selection of maintenance and rehabilitation (M&R) techniques with little regard given to life-cycle costing or to priority as compared to other pavement requirements in network (SHAHIN, 1998).

Many traditional systems were used to evaluate and classify pavement surface distresses. Conventional visual and manual pavement distress analysis techniques are very costly, time-consuming, dangerous, labor-intensive, tedious, and subjective. They have a high degree of variability; are unable to provide meaningful quantitative information; and almost always lead to inconsistencies in distress detail over space and across evaluations (JASELSKIS, 2009). In this research work new technologies will be used for this purpose. It is anticipated the usage of mobile phone camera in order to collect and analyze different distress data at Irbid city roads.

The usage of this system is anticipated to: collect the distress data safely, perform real-time operation, extract highly accurate data, and develop a new high technology system that produces spatial and attribute data concerning distress evaluation and analysis, and introducing maintenance priorities according to distress severity and other integrated factors (SHUBINSKY, 2009).

Photogrammetry is defined as “The art, science, and technology of obtaining reliable information about physical objects and the environment by recording, measuring and interpreting photographic images”, when the maximum object-to-camera distance of about 300m, this is called close-range Photogrammetry. Close-range photogrammetry has many applications like, architecture, gauging, manufacturing, and industrial engineering (SMITH, 2007).

1. Introduction

The distribution of distresses cracks in Irbid city is one of most important issues for the society because there is a rapid increasing in the number of cracks locations in Irbid city. The collected variables in this study included: age of pavement, Average Annual Daily Traffic (AADT), section crack area, type of distresses, severity levels of distresses, and length & direction of distress cracks. Statistical regression were carried out to establish useful models to estimate cracking quantities from the mentioned database variables.

1.1 Significance of the study

- The Pavement Management System (PMS) is a set of tools or methods that can assist decision makers in finding cost effective strategies for providing, evaluating, and maintaining pavements in a serviceable condition to provide the information necessary to make these decisions.
- The development of such an automated system was anticipated to open the door to automatically collect, classify, and predict pavement surface roads conditions. It will give the guidelines to the maintenance engineers to follow up technology trends rather than using manual measurements and operations. Therefore, real- time operations and maintenance prioritization are expected.
- The Fact that the usage of mobile phone camera adds more significance for the study.

1.2 Objectives of the study

This study has the following objectives relating distresses measurements in Irbid city

- To Investigate the potential of mobile camera systems setup in obtaining automated quantities of Alligator cracking and Longitudinal& Transverse cracking happening to some factors influencing crack behavior, such as age of section, Area of section and Average annual daily traffic(AADT) of the section.
- To Develop a statistical models using SPSS Package Software for distresses quantities involvement as function of variables affecting cracks behavior.
- To Identify of critical areas, if any, for future research and development.

1.3 Study area

- Irbid city was being selected to be the study area.
- Irbid city which is located Longitude 35° 45ˉ and 36° 00ˉ east and between Latitudes 32° 30ˉ and 32° 45ˉ north, as shown in figure 1.1

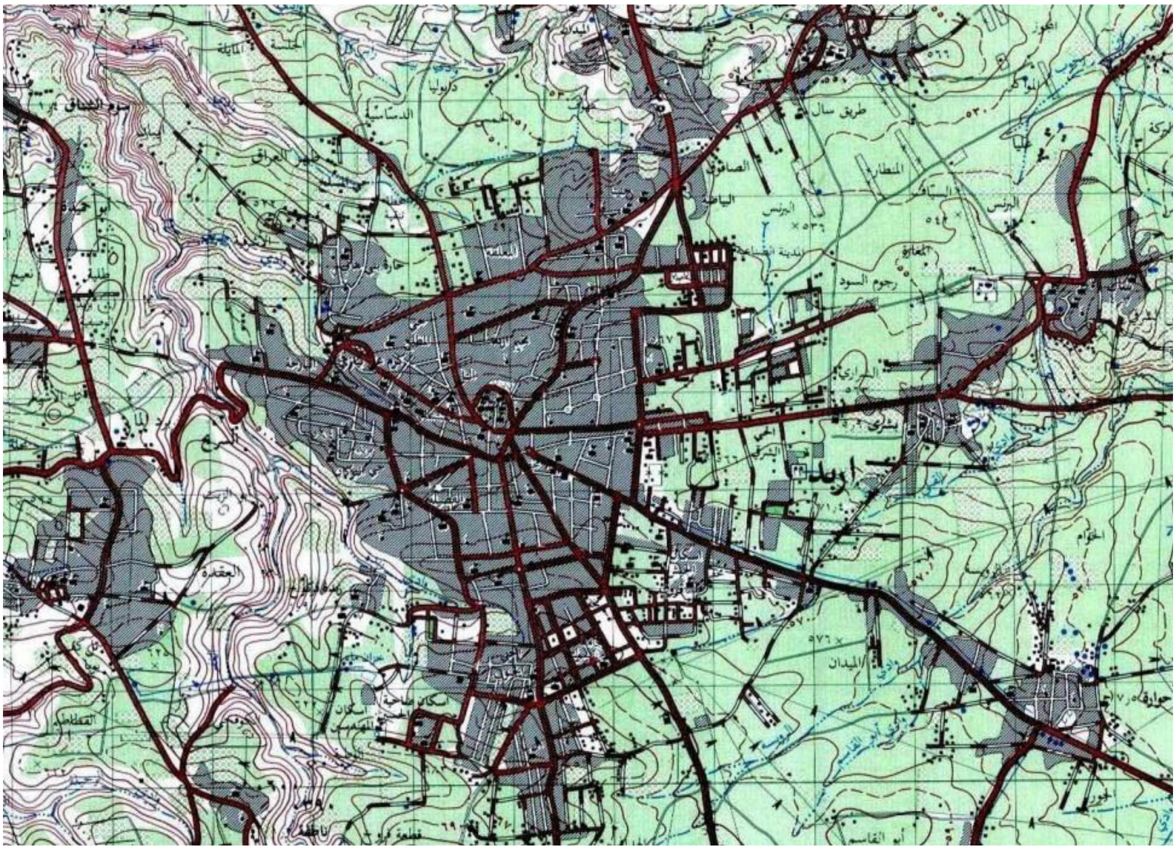

Figure 1.1: Irbid Study area

2 Research data and Methodology

The research data and methodology can be divided into components:

- Data acquisition and collection: Real digital images were collected using mobile phone camera for specific locations at various times (peak hours and off-peak hours). Random locations were selected in Irbid city for the purpose of implementation of this study.
- Image analysis: The captured images were used for two purposes: 1) to visualize the type of distress and 2) to quantify length and direction of cracks.
- Statistical Analysis: SPSS statistical package was used to develop models that show the relation between automated quantities of cracks as function of age of crack section, AADT of crack section, and area of section. Statistical analysis scheme was performed to predict quantities of cracks as function of the previously mentioned independent variables.
- Results Analysis, Conclusions, and Recommendations: The findings were discussed and analyzed in order to study the feasibility, potential and limitations of the proposed research work. Proper conclusions and recommendations were drawn.

2.1 Data acquisition and collection

Collected data could be divided into:

1. Data measured using the Mobile Phone Camera;
2. Data collected by visualization with the aid of Mobile Phone Camera
3. Data collected from Irbid-Municipality like age of section and AADT of that section.

2.2 Image Analysis

- The measured data using Mobile Phone Camera for every location included:

1. Image coordinates of vehicles through its path a long the road, in the field of view of the mobile camera. The x-coordinates of vehicle image was recorded while having the camera in the play. The x-coordinate was representing the direction movement in the mobile camera. Normally a point on the hood of the vehicle was selected as a reference point for measurements.
2. Thus, knowing the coordinates, length and direction of cracks

- The Data collected by visualization with the aid of mobile camera included:

1. Type of distress.

- Data-base of the Study

For the purpose of checking the precision and accuracy of the collected distresses data that include distress type, distress quantity and severity level of the observed distress that was obtained through analyzing the obtained photographs from the camera for the distressed locations .The results of analysis, comparison and validation between manually collected distresses data and photogrammetric ally analyzed data are summarized in table 2.1 below. This table contains the following pieces of information:

1. Types of distresses visible through images associated with there severity levels.
2. Distresses quantity obtained through camera analysis in m, m^2 or number units.
3. Distresses quantity obtained manually in m, m^2 or number units
4. Difference between manual and automated collected distress quantities:

Difference = | (camera-based quantity)- (manual-based quantity)| 2.1

5. Error or Bias percentages of the automatically collected data from accurate manual data:

% Bias= (Difference ÷ Manual Measurement) x 100% 2.2

6. Percentages of accuracy of the automatically collected data:

% Accuracy = 100 - % Bias 2.3

Table 2.1

Sample Output of Validation Process

Types of Distresses in Photograph & Severity	Camera Analysis Quantity	Manually Identified Quantity	Diff	% bias	% Accuracy
Alligator Cracking (H)	46.28m^2	10.72*4.25 =45.56 m^2	0.72	1.58	98.42
Alligator Cracking (H)	11.79m^2	2.75*4.1 = 11.28 m^2	0.52	4.57	95.43
L&T Cracking (M)	24.98 m, w=2.5cm	24.45m, w=2.3cm	0.53	2.17	97.83
L&T Cracking (M)	15.39m, w=3.6cm	15.2m, w=3.3cm	0.19	1.25	98.75
Alligator Cracking (M)	5.55m^2	1.42*3.75 = 5.33 m^2	0.22	4.13	95.87
L&T Cracking (M)	13.49m, w=1.45cm	13.25m, w=1.6cm	0.24	1.82	98.18
Alligator Cracking (H)	5.63 m^2	3.62*1.49 = 5.4 m^2	0.23	4.26	95.74
L&T Cracking (M)	5.87m, w=1.3cm	5.82m, w=1.45cm	0.05	.86	99.14

7. Estimate Average of Accuracy, Standard Deviation of Accuracy, and coefficient of Variation of Accuracy as shown in table 2.2 below.

Table 2.2

Validation Process Accuracy Results

Average of Accuracy	96.49%
Standard Deviation of Accuracy	2.21%
Coefficient of Variation of Accuracy (COV)	2.29

Obviously, from table 2.2 and because the average accuracy of the system was about 96.5% in the measurements mode, this validation process showed a promising usage of this system so this system is a step toward full automation point in order to relieve the entire hazard that accompanied the traditional manual data collection techniques.

2.3 Development of Alligator Cracking and Longitudinal and Transverse Cracking Model

Model development was a major part of this study. Therefore, statistical regression analysis was adopted to develop predictable models that can be utilized to estimate quantities of cracks from the studied variables.

The previous independent variables were selected and identified based on the following criteria:

1- Regression analysis using SPSS Package software in order to select the most significant variables

2- Drawing of scatter plots to show the pattern of relationships among variables and various observations related to investigated variables.

2.3.1 Modeling and Results of Analysis

2.3.1.1 Linear Multiple Regression of Alligator Cracking

The following model was developed to predict Alligator cracking distress quantities on different sections:

Alligator Cracking Quantity = 16.123* (Area of section) +136.695* (Age) - 103.532*(AADT) 2.4

Where;

Area of section = Area of section contain cracks

Age= Age of section contains cracks

AADT=Average Annual Daily Traffic of section contains cracks.

Table 2.3 lists the statistical characteristics of this model. As shown in this table, the developed model is statistically significant with coefficient of multiple regression determination (R2) = 0.416 This means that about 41.6% of alligator cracking quantities variation can be explained by the included independent variables. The coefficient of multiple determination was very close to adjusted coefficient of multiple determination, which suggests that the model is strong and predictable. Table 2.4 list the variables entered in the model and their T- value. The model had a small standard error of estimates. Figure 2.1 predicts the predicated values of this model versus the measured values.

This model shows that the overtake alligator cracking quantities, which is a measure for crack behavior, could be predicted if the following variables are known: Area of crack section, Age of section, and AADT of crack section.

Table 2.3

Statistical characteristics of the linear model

Multiple R	0.645
R-square	0.416
Adjusted R-square	0.319
Standard error	22.8979
DF	18
Sum of Squares	9437.655
Mean Square	524.314
F- Value	4.278
α - Level	0.0002

Table 2.4

Variables entered in the model and their T- value

Variable	T-value
Area of section	-0.559
Age of section	1.953
AADT	1.667
Constant	1.645

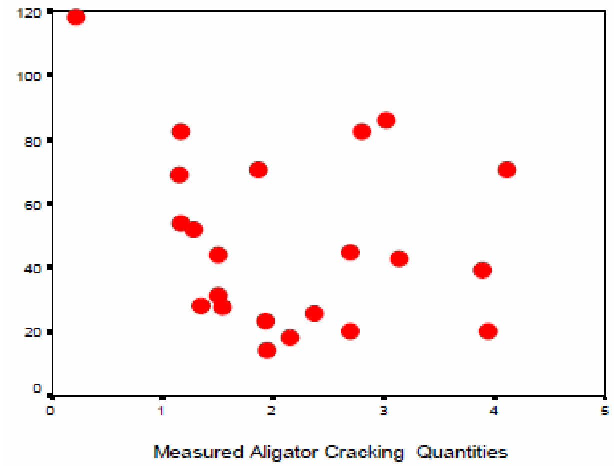

Figure 2.1: Scatter Plot of Alligator Cracking Quantities Measured v.s Alligator Cracking Quantities Predicated of the linear model

2.3.1.2 Linear Multiple Regression of Longitudinal and Transverse Cracking

The following model was developed to predict Longitudinal and Transverse (L&T) cracking distress quantities on different sections:

(L&T) Cracking Quantity= 4.258*10-4 *(AADT) + 17.103*(Age0 -3.185*10 -4 *(Section Area)-89.478 2.5

Where;

Area of section = Area of section contain cracks

Age= Age of section contains cracks

AADT = Average Annual Daily Traffic of section contains cracks.

Table 2.5 lists the statistical characteristics of this model. As shown in this table, the developed model is statistically significant with coefficient of multiple regression determination (R2) = 0.347 This means that about 34.7% of alligator cracking quantities variation can be explained by the included independent variables. The coefficient of multiple determination was very close to adjusted coefficient of multiple determination, which suggests that the model is strong and predictable. Table 2.6 list the variables entered in the model and their T- value. The model had a small standard error of estimates. Figure 2.2 predicts the predicated values of this model versus the measured values.

This model shows that the overtake alligator cracking quantities, which is a measure for crack behavior, could be predicted if the following variables are known: Area of crack section, Age of section, and AADT of crack section

Table 2.5

Statistical characteristics of the linear model

Multiple R	0.589
R-square	0.347
Adjusted R-square	0.238
Standard error	24.2122
DF	18
Sum of Squares	10552.166
Mean Square	586.231
F- Value	3.192
α - Level	0.0002

Table 2.6

Variables entered in the model and their T- value

Variable	T-value
Area of section	-0.267
Age of section	2.597
AADT	0.764
Constant	1.028

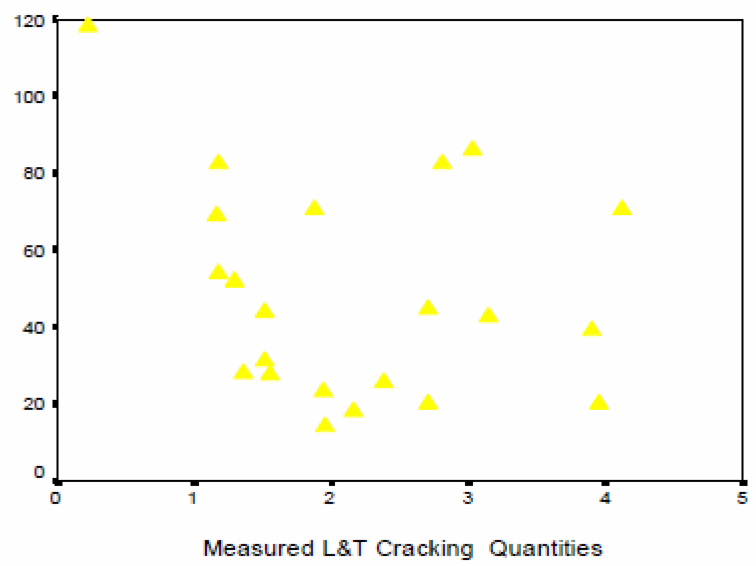

Figure 2.2: Scatter Plot of L&T Cracking Quantities Measured v.s L&T Cracking Quantities Predicated of the linear model

3. Discussion of the results

Results of this investigation indicated that

- Various predication models for each type of distresses were developed. Number of variables that include {Average Daily Traffic(ADT), Pavement Age, and Section Area} were selected to show their effect on distress generation using the Linear multiple regression model.
- Results indicted that in most of the developed predication models, ADT and Pavement age variables play the most important role in the distresses development with higher effect of the pavement age variable in distress generation.
- Area of section contains cracking is found to have non significant contribution to distresses quantities.
- Its worth to mention that all above distresses predication models were developed through utilizing ADT, section area, and pavement age variables with suitable transformations. Other variables may be important such as pavement materials characteristics, pavement structure, foundation properties and other variables were not included in these models. The absence of such variables was due to lack of available data concerning these variables on Irbid Municipality. So research needs

to be preformed to provide the required data for these variables to build stronger models.

- Most of Irbid sections suffering from alligator cracking distress type. Since this type of distress is mostly related to traffic repetition this might indicated a traffic management problem over the city where they are exposed to higher traffic levels than they designed for.

4. Conclusions and Recommendations

- Data acquisition for pavement distresses using such automatic system proved to be quick, unlike manual data collection which consumes time, money and labor. This in turn showed a great potential of time saving through the use of digital data reduction procedures.
- Surface measurements as well as decision making have been validated and actually tested for all distresses types. The developed system showed a great accuracy potential in both measurement mode and decision making phase. This result opened the door for automatic distresses classification potential without any human intervention.
- The analysis dealt with issues related to the objectives mentioned in this study. I hope that this study will help both government municipalities related to distresses maintenance and people who concern in order to take right decisions about this problem & its relationship to transportation issues in society of Irbid city and other factors.
- Usage of Mobile camera phone setup was proven to be useful, practical, and accurate camera configuration and data acquisition system for distresses studies.
- Futher studies are needed to expand the usage of mobile camera phone setup in transportation engineering.
- It is recommended to make use of the developed system to perform more iterations in order to reach the full automation case of pavement condition recognition and collection.

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The use of solar energy for air-conditioning in the cold season by employing a heating pump on lithium bromide - water solution

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Abstract: *The authors of the present paper discuss the results following the monitoring of a refrigerating plant's performances with absorption of lithium bromide -water solution, where the evaporator, representing the cold source, is fed with hot water prepared in a system of solar panels. Furthermore, they include a working scheme which can be used in both hot and cold seasons, resulting in a substantial reduction of the conventional energy use, with a direct effect on the protection of the surrounding environment.*

Keywords: renewable energy source, environment protection

Nomenclature

c_p	specific heat capacity, [kJ/kgK]	*Subscripts*	
COP	performance coefficient, [-]	*A*	absorber
f	circulation factor, [-]	*C*	condenser
h	specific enthalpy, [kJ/kg]	*G*	heat generator
Q_{m0}	refrigerant masic flow rate, [kg/s]	*SC*	strong LiBr solution
Q_m	masic flow rate, [kg/s]	*SD*	weak LiBr solution
		w	water
Greek letters			
Φ	heat flux, [kW]		
ξ	LiBr concentration		

1. Introduction

The use of renewable energy sources has become a standard in the industry of new constructions. The plants which work on solar energy are designed foremost for preparing household hot water and for feeding the generator of refrigerating machines with absorption during the hot season. Such a case was studied by the present authors in article [1].

A contemporary challenge is adapting the above mentioned plants so that they can use solar energy also in the cold season, by working in heat-pump regimes. As a result of this, especially in winter days with clear skies, a significant quantity of energy can be captured. Marcos and Izquierdo [2] recorded in the case of a 42 sq. meters surface of solar panels which provides for an 80 sq. meters laboratory, with temperatures up to 70 °C for the thermal agent in the cold season.

Clausse and Alam [3] used solar energy for air heating, recording in the case of 16 solar panels positioned on a surface of 38,7 sq. meters the delivered warm air's temperature, the value of which was 2 °C below the comfort temperature inside the rooms. Although solar energy does not fully cover the requirements of air heating, it becomes noticeable that conventional sources are significantly less used; this fact has implications on the protection of the surrounding environment.

Yamankaradeniz and Horuz [4] developed a similar study, by monitoring the characteristics of a heating pump driven by a solar circuit in clear summer days for Istanbul's area. The analysed characteristics included the thermal power of the condenser and the plant's performance coefficient.

In the sections below the authors will present alterations made to the summer time feeding system of the refrigerating plant and will include a calculus of the plant's performance.

2. Experimental stand

The experimental stand is represented by the following composing elements:

- a system of 30 solar panels with a total surface of 80 sq. meters, which can provide a maximum thermal power of 40 kW in the hot season;
- a system for capturing and storing the panels delivered energy consisting, first, of a plate heat exchanger - here is where takes place the heat exchange between the etilenglicol – water solution belonging to the solar system and the softened water belonging to the rest of the plant, as well as, second, of a storage tank with a volume of 4000 l;
- the water consumer, where the water was prepared in the solar system and used for driving the plant's boiler in the hot season or for ensuring the necessary heat for boiling the refrigerating agent in the evaporator;
- a classic system for warm water preparation composed by a boiler with a thermal power of 50 kW, driving on gas fuel. This boiler fully covers the heat requirements for the cold season.

The refrigerating plant with a lithium-water bromide solution absorption is of a reversible type and thus can be used for cooling the air in the warm season, as well as for warming the air in the cold season, while in the warm season takes on the role of filling in the heat requirements for this equipment during days with low insolation.

The refrigerating agent used in this type of plants is water with vaporization temperature between 3 -5 °C. The advantage here is the notable difference between the components' boiling points, thus obtaining increasingly pure vapours of refrigerating agent, as a result of the desorption process without the need of their ulterior rectification.

Logistics wise, several sensors were used, as follows:

- type K (*NiCr- Ni)* thermocouples of ± 0.25 K accuracy, for temperature monitoring for the measurement sections, as well as for the ambient air;

- flowmeters with ± 3 % accuracy, with ultrasounds for water debit monitoring on the system's different circuits;
- piranometers for measuring the total solar radiation intensity formed by direct and diffuse radiations alike;
- anemometers for measuring the air's speed;

3. Methodology

The aim of the present study was, on one hand, to determine the thermal energy prepared in the cold season and, on the other hand, to establish the boiler's supplementary input in order to ensure the temperature level for the plant's evaporator.

Based on the measured values it was determined the heat flow delivered by the solar panels $\dot{Q}_{CS}$ that is equals with the heat flow received by water $\dot{Q}_a$ in the plate heat exchanger.

The heat flow, $\dot{Q}_{CS}$, was calculated by using the following relation:

$$\dot{Q}_{CS} = \dot{m} \cdot c_{p,EG} \cdot \Delta\theta, \text{ [kW]} \quad [1]$$

where:

- $\dot{m}$ - the masic flow rate for thermal agent in the solar panels system, [kg/s];
- $c_{p,EG}$ - the specific heat at a constant pressure of the water - etilenglicol solution in the solar plants system's circuit, for an average work temperature in the system, [kJ/(kg K)];
- $\Delta\theta$ - the temperature difference between the entrance and exit points in the plate heat exchanger, [°C];

The thermic agent's volume debit in the solar sensors system, as it was determined by using the ultrasounds flowmeters, has a value of 1,2 m^3/h. Similarly was determined also the hot water flow rate in the circuit plate heat exchanger – tank, resulting in a value of 1,8 m^3/h.

The necessary flow to be delivered by the auxiliary source, the boiler, was determined in such a way so that the thermic agent obtained would have a temperature of 15 ºC, considering the flow required by the refrigerating machine's evaporator.

4. Results

The monitoring process took place in the period between late December 2011 and late February 2012.

From within this period, present here is the values variation of the daily average heat flows as delivered by the solar plants system and by the boiler for the 16.01.2012-23.01.2012 time interval, considered to be representative for all possible situations. The heat rates are dependent on the meteorological conditions in the corresponding days, especially external temperature and solar radiation, but also on the heat accumulation resulted in the storing tank throughout the previous days.

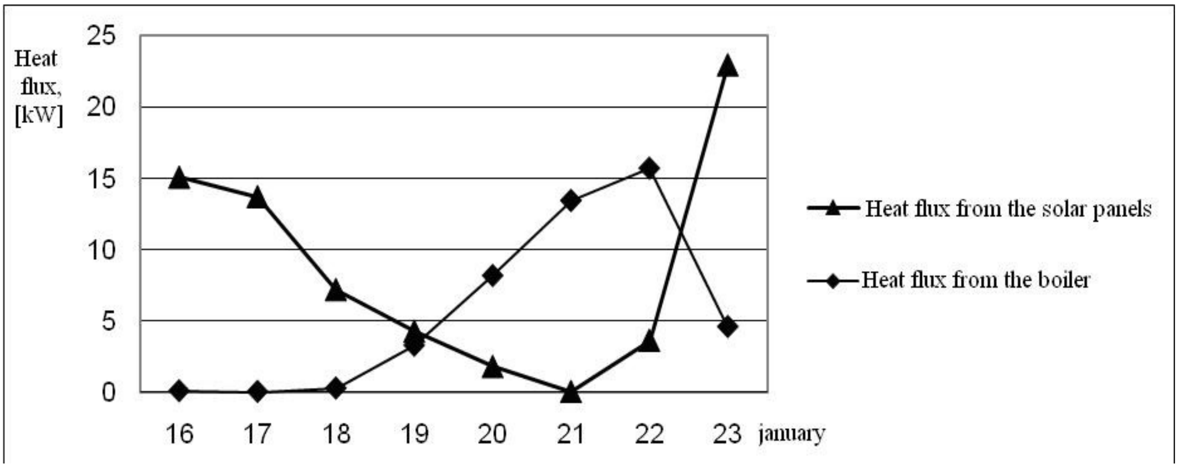

Figure 1. Variation of the yielded flows in the 16.01.2012- 23.01.2012 period

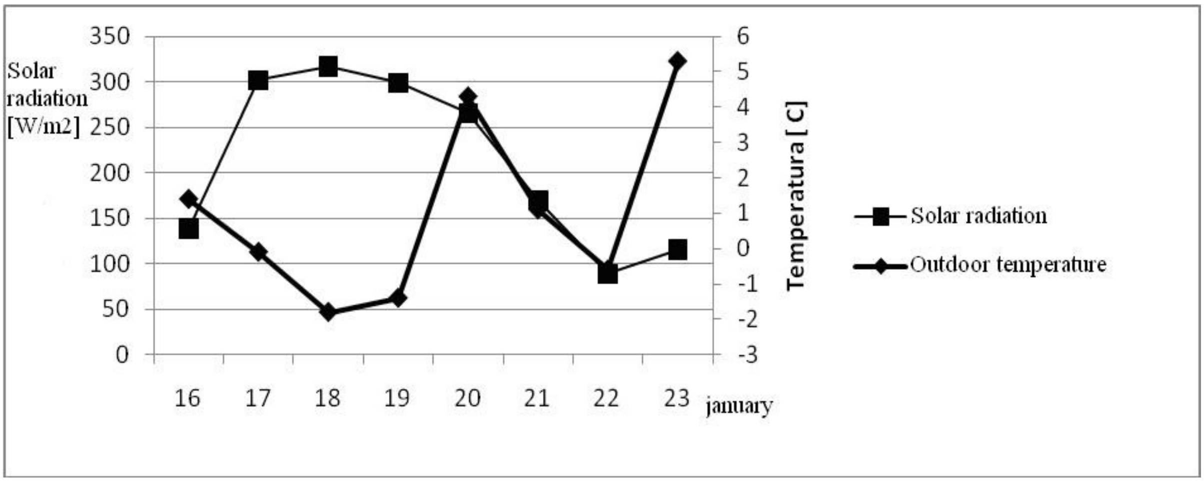

Figure 2. Variations of the ambient temperature and the solar radiation in the 16.01.2012- 23.01.2012 period

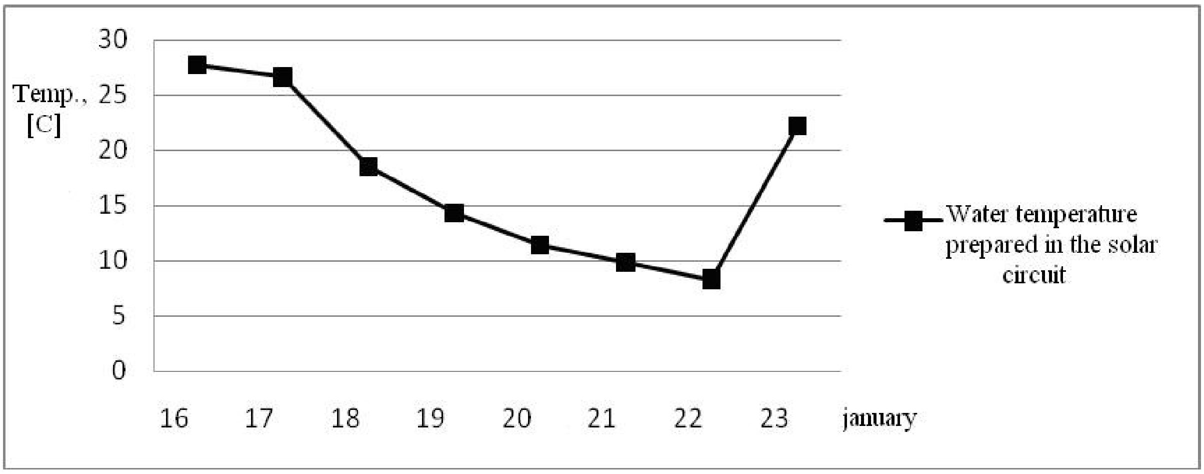

Figure 3. Variation of the warm water prepared through solar processes in the 16.01.2012- 23.01.2012 period

By analysing the profile of the heat flow yielded by the solar sensors – Figure 1 – together with the profile of the solar radiation's intensity – Figure 2 – a correlation between the two becomes noticeable, namely that in the time period 16th – 19th of January, corresponding to a maximum intensity for the period studied, the solar panels covered fully the heat required by the evaporator.

On the other hand, on the days of 20th – 22nd of January the sky was grey, which is why the flow yielded by the solar sensors reached values close to zero.

The water's average temperature when leaving the heat exchanger on the solar panels side within the time lapse of 08.00 – 16.00 o'clock, had a value of 15-20 °C.

Figure 2 illustrates that the solar radiation is not influenced directly by the external temperature, but depends on the degree of sunlight.

Figure 3 is a representation of the variation of the water's daily average temperature, where the water receives heat from the etilenglicol-water solution throughout the studied period. It can be noted that this temperature is variable, but nevertheless close to the value required by the authors for the heat pump's evaporator. In order for this variation's influence to be diminished, the plant's scheme includes a blending tank provided for driving the evaporator.

5. Discussions

In the section below the authors present the scheme of the plant which operates on hot water prepared by the solar panels and the auxiliary source in the cold season.

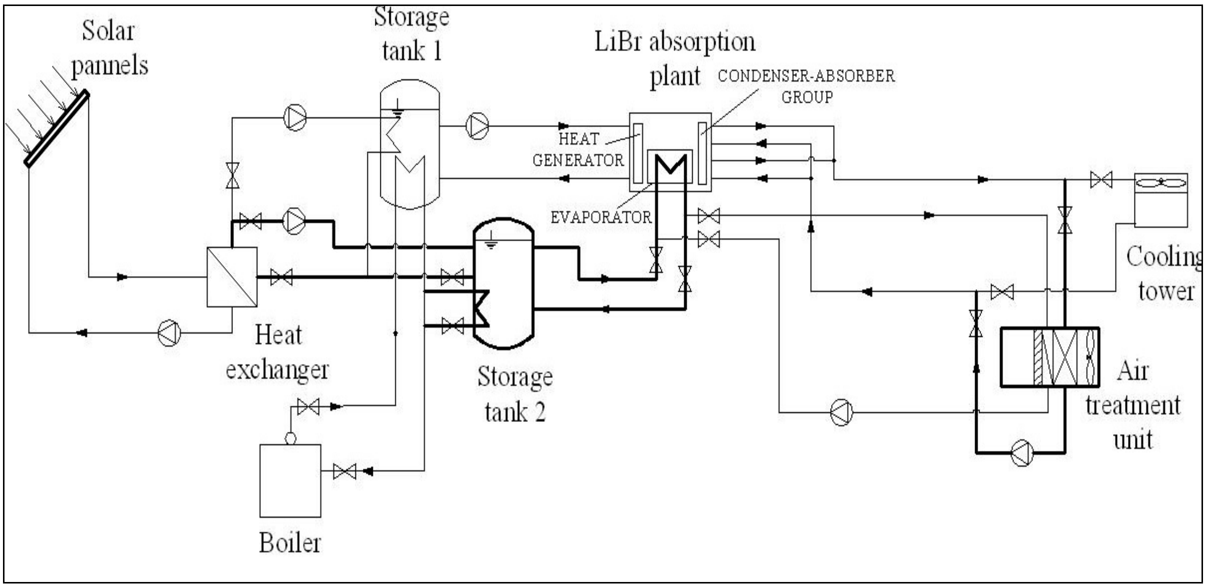

Figure 4. The plant's scheme, with focus on the circuit in winter conditions

The driving principle is as follows:

In the solar panels hot water is prepared, reaching an average temperature of 15°C, and when such a temperature cannot be reached, supplementary heat is used in the evaporator's driving tank - Storage tank 2, with the water prepared in the boiler. This water is used as energy source which enters the absorption refrigerating machine's evaporator. The absorption refrigerating machine operates as a heating pump (PC), with the generator driven by 80- 85 °C hot water, and yields condensation and absorption heat in the heating battery belonging to the air treatment plant, where the air is heated up to a temperature of 27 – 30 °C.

The thermal calculus

The absorption refrigerating plant with a lithium-water bromide solution is presented in Figure 5.

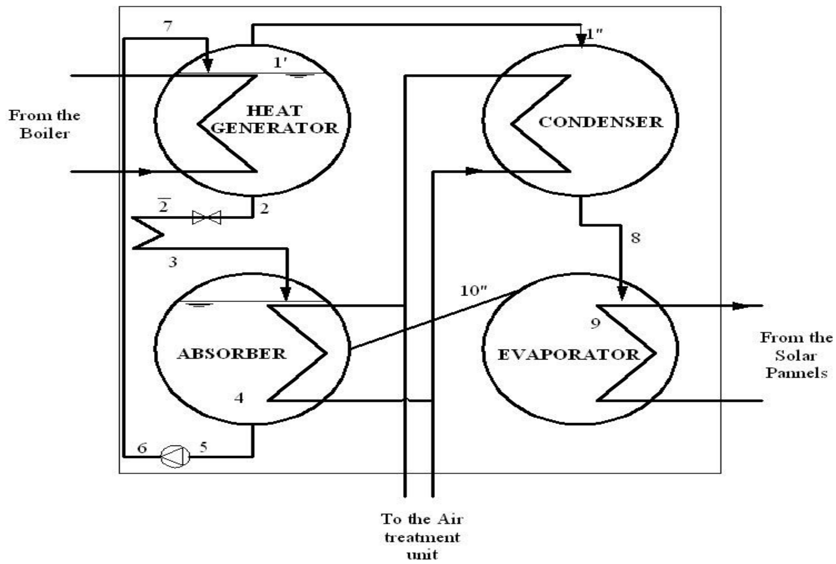

Figure 5. The absorption machine with lithium-water bromide solution

The thermodynamic cycle corresponding to the absorption refrigerating plant with a lithium-water bromide solution is represented in diagram h - ξ (Figure 6).

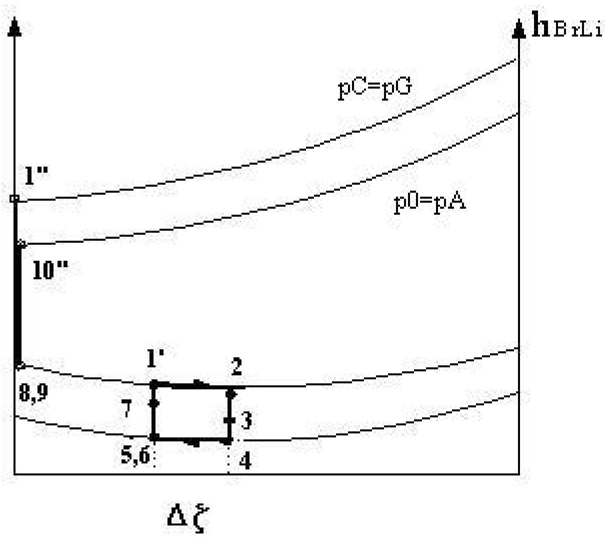

Figure 6. The plant's theoretical thermodynamic cycle

The plant is used for warming the air in habitable spaces during the cold season. The warm water, which represents the thermal agent in the air's heating battery, is waste heat resulted from cooling the condenser and absorber in the absorption refrigerating plant. In order for the plant to operate in the cold season a hot source is required, represented by warm water prepared in the solar panels and by hot water prepared in a boiler with gas fuel.

Known factors:

- refrigerating capacity, Φ_0= 12 kW*;*
- temperature values of the cooled water , $\theta_{w3} / \theta_{w4}$= 12/7 ºC;
- temperature values of the warm water to the condenser, $\theta_{w5} / \theta_{w6}$= 27/31 ºC.

Admitted factors:

- the difference between concentrations, $\Delta\xi = \xi_{SC} - \xi_{SD} > 5\%$;
- pressure loses are insignificant (the vapours' circuit is very short), respectively $p_A = p_0$; $p_G = p_C$;
- the work pumping of the pumps, *P*, is insignificant.

Factors to be determined:

- the flow rate for the concentrated solution Q_{mSC} and diluted Q_{mSD} as well as for the refrigerating agent Q_m;
- the plant's thermal driving power, Φ_G;
- the thermal powers yielded to the cooling water Φ_A, Φ_C;
- the plant's energetic balance sheet;
- the plant's performance coefficient, COP.

The plant's operating regime (represented by the vaporisation temperature and pressure, as well as by the condensation temperature and pressure) was based on the temperature variations in the case of the working fluids in both evaporator and condenser, as well as on the minimum temperature difference between one medium and the other ($\Delta\theta_0 = \Delta\theta_C = 3$ °C), as follows:

$$\theta_0 = \theta_9 = \theta_{10} = \theta_{w4} - \Delta\theta_0 = 4 \text{ °C} \quad (2)$$

$$\theta_C = \theta_8 = \theta_{w6} + \Delta\theta_C = 34 \text{ °C} \quad (3)$$

Subsequently, based on the water tables, the vaporising and condensing pressures can be determined:

$$p_0 = f(\theta_0) = 864.8 \text{ Pa}$$

$$p_C = f(\theta_C) = 5354 \text{ Pa}$$

The difference between concentrations is determined by the temperature variations of the fluids in the boiler and absorber alike and by the minimum temperature difference between the ($\Delta\theta_G$ = 3 °C, $\Delta\theta_A$ = 5 °C). starting from diagram h-ξ-p, the solution's concentrations are determined:

$$\xi_{SC} = \xi_2 = f(p_G, \theta_2 = 80 \text{ °C}) = 61 \%$$

$$\xi_{SD} = \xi_5 = f(p_A, \theta_5 = 32 \text{ °C}) = 54 \%$$

From both specific thermal and energetic balance sheets for the plant's devices, the specific powers are determined (reported to the refrigerating agent's flow rate, Q_m) and consequently, by multiplying them with the above mentioned debit. Table 1 contains a synthetic presentation of mass and heat balance equations for every heat exchanger (H.E.)

Table 1

Energy balance for the heat exchangers

H.E.	Energy balance	Results
Generator	$q_G = h_{1''} + (f-1)\cdot h_{2'} - f\cdot h_7$ $Q_{mSC} = Q_{mSD} - Q_m$ $Q_m = \frac{\Phi_0}{q_0}$ $Q_{mSD}\cdot\xi_{SD} = Q_m\cdot\xi_{1''} + Q_{mSC}\cdot\xi_{SC}$ $f = \frac{\xi_{SC}}{\xi_{SC}-\xi_{SD}}$	$q_G = 3432$ [kJ/kg] $Q_{mSC} = 0.039$ [kg/s] $Q_m = 0.05$ [kg/s] $Q_{mSD} = 0.044$ [kg/s] $f = 8.71$ [-]
Absorber	$q_A = h_{10''} + (f-1)\cdot h_3 - f\cdot h_5$	$q_A = 3401$ [kJ/kg]
Evaporator	$q_0 = h_{10''} - h_9$	$q_0 = 2365$ [kJ/kg]
Condenser	$q_C = h_{1''} - h_9$	$q_C = 2413$ [kJ/kg]

The thermal powers, corresponding to each component device within the plant (generator, absorber, condenser) are determined by multiplying the masic powers by the refrigerating agent's flow rate,Q_m.

The plant's energetic balance sheet was developed according to the relation:

$$\Phi_0 + \Phi_G = \Phi_A + \Phi_C \text{ [kW]} \tag{4}$$

$$12 + 17.41 = 17.25 + 12.24 \Rightarrow 29.41 = 29.49$$

The energetic balance is closing with a deviation of 0.2 %.

The plant's performance coefficient, COP, was determined with the relation below:

$$COP = \frac{\Phi_C + \Phi_A}{\Phi_G} = 1.69 \tag{5}$$

The heat flux provided by the condenser and absorber can be used in a air handling unit for space heating with a volume of approximately 600 m^3, in the cold season.

6. Conclusions

Based on the graphs presented by the authors, as well as on the discussions following the performance monitoring for the solar panels set in contact with the lithium-water bromide type plant in the cold season, it can be concluded that significant energy savings can be achieved by performing small constructive alterations of the plant designed for the hot season.

Throughout the monitored period, the water's daily average temperature in the solar circuit was of approximately 15 °C, and on the days with clear sky the solar panels covered totally the heat requirements for the refrigerating agent's vaporization in the cold source.

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UTILIZAREA ENERGIEI SOLARE PENTRU CLIMATIZARE IN SEZONUL RECE CU AJUTORUL UNEI POMPE DE CALDURA CU SOLUTIE BROMURA DE LITIU – APA

Abstract

In lucrarea de fata autorii prezinta rezultatele monitorizarii performantei unei instalatii frigorifice cu absorbtie cu solutie de bromura de litiu – apa la care vaporizatorul, reprezentand sursa rece, este alimentat cu apa preparata intr-un sistem de captatoare solare. Este prezentata o schema de lucru care poate fi folosita atat in sezonul cald, cat si in sezonul rece, avand ca rezultat o reducere substantiala a consumului de energie conventionala, cu efect direct in protectia mediului inconjurator.

Cuvinte cheie: surse de energie regenerabile, protectia mediului

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Water flow adjustment of pumps in heating stations

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Abstract. *In urban heating stations the heat agent circulation between the energy source and consumers is assured by pumps, which take part to the energy consumption of the system in the operation period. The number, the position, and the technical characteristics of these pumps are established according to the chosen type of the heating system, the thermal power and the operating regime. Using variable rotation speed pumps it is possible to have a continuous control over the water pressure according to the thermal load at a certain moment. In this paper are presented and analyzed some optimization solutions of pumps operation in urban heating stations from energy point of view.*

Key words: heating stations, energy saving, variable speed centrifugal pump, variable frequency drives

1. Introducere

Heating stations are dimensioned to provide the consumers energy need in the coldest period of the year. However, most of the energy need is much lower than the designed value of the heating station thermal load. Consequently the primary agent flow must be reduced most of the time from heating season. This flow variation can be carryed out for constant speed of centrifugal pup using following methods: by-passing a part of the water discharge (the pump operates at the same operation point and the absorbed power remains constant); by introducing a supplementary pressure loss (ΔH), using a regulating valve (the operation point is heading towards left in H-Q diagram) [1-6]. Another method is to operate with variable rotation speed pumps. [4-8]

2. Thermal load of the heating stations

In Figure 1, the yearly distribution of the daily average outdoor temperature is presented. The diagram points out the fact that, in the year, the lowest temperatures represent about 5 %. Thus, if the heating station is dimensioned to cover the maximal energy need, then 95 % on the year the station is over dimensioned. At the same time, it can easily be seen that approximately 40 % of the year the average temperature is higher than +15 °C. Thus, 40 % of the year the thermal energy provided by heating station is used only to prepare the domestic hot water, which needs only a small part of the installed capacity of the heating station.

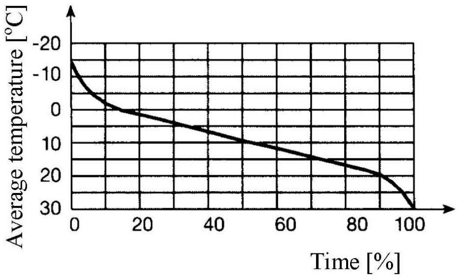

Fig.1 Average external air temperature in time

At constant difference between the forward and return temperatures of the warm water, the delivered energy do not varies proportionally with the discharge. Generally, at constant forward temperature the return temperature is lower when the required heat decreases.

In Figure 2 is presented the relative produced heat quantity depending on the relative discharge at constant forward temperature of the warm water. When the water discharge is reduced, for example at 60 % of the initial value, the produced heat quantity decreases only at 85 % of the initial value, because the water-cooling is increased.

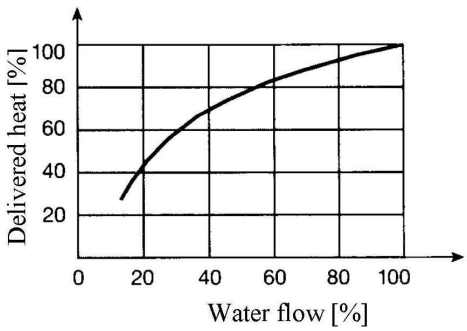

Fig. 2 Relative amount of heat delivered in time
for constant forward temperature

The main goal in operating a heating system is to assure the consumers with the required heat flow according to outdoor climatic parameters. Thus, the heating system is provided with a regulation system, which can be qualitative, quantitative or mixed.

The quantitative adjustment requires a variation of the flow during the operation, the warm water parameters being constant. It can be done by:

– pumps with different technical characteristics (flow, pumping head);

– variable rotating speed pumps.

The assurance of the required heat flow, demand an adjustment in the distribution system between the heat source and consumers. Depending on the applied methods, important variations of the energy consumption are obtained. In Figure 3 the energy consumption curves for different adjustment methods are presented.

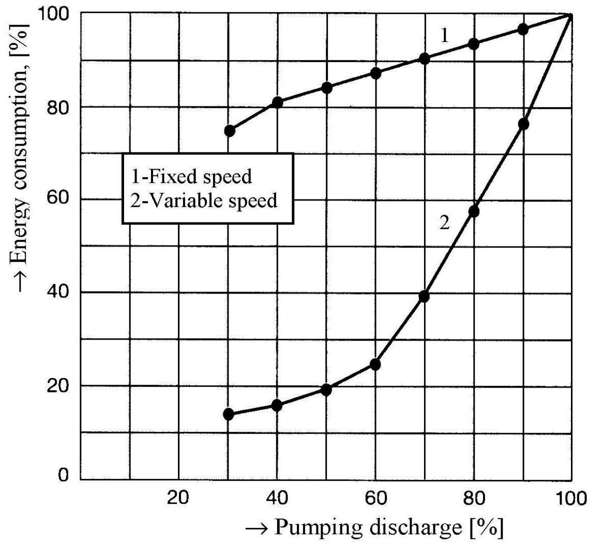

Fig.3 Energy consumption for variable flow

The variation of energy consumption depends on the global efficiency of the heating system, the configuration of the distribution system, the operation point and the type of the adjustment equipments.

Analyzing the presented curves one can observe that the energy consumption in the case of regulating valves is higher than the energy consumption in the case of variable rotation speed pumps.

The throttling valve control method of reducing water flow is presented in Figure 4.

The characteristic curve of the system $H_{r1}=f(Q)$ establishes the nominal pump operation point in F, according to H_F pressure head, Q_F water discharge and the specific pumping energy w_{pF} [5].

Shutting partially the pumps outlet the systems characteristic curve becomes $H_{r2}=f(Q)$ and, according to new operation point the water discharge will decrease to Q_o, the pumping head will increase to H_o, the specific pumping energy will decrease to $w_{po}=w_{p\min}$ and the efficiency of the pumps will increase from η_F to η_o.

The higher pumping head will lead to a lower hydraulic efficiency of the system and finally to a lower global efficiency. From this reason the water discharge regulation with regulating valves is avoided in practice [3], [7]. However, examining the specific pumping energy curves w_p, one can be observe that the global efficiency of the system increases even when the hydraulically efficiency is decreasing. This is possible when the regulation is done under the point O that corresponds to the minimal specific pumping energy, on the characteristic curve of the pump. If the regulation is made above the point O by increasing the pumping head, then the specific pumping energy increases, leading thus to an increase of the energy consumption.

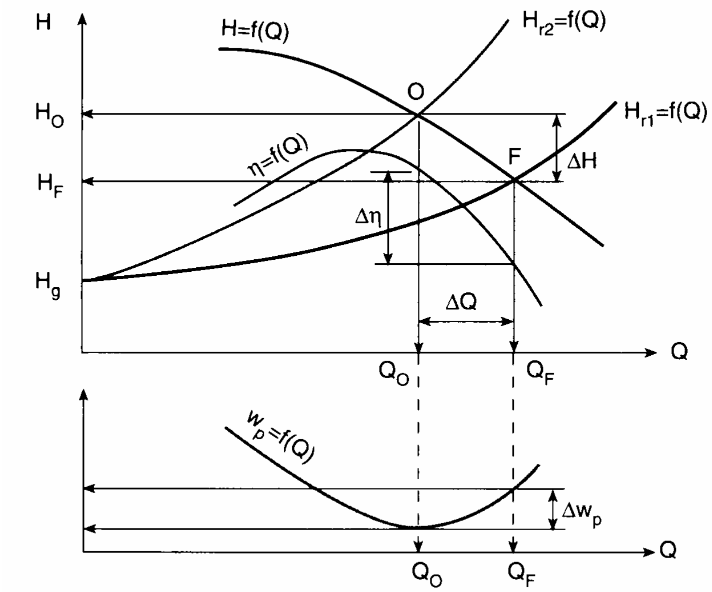

Fig.4 Flow variation by throttling valve

Thus, the operation diagram of a centrifugal pump can be separated in two areas divided by the operation point corresponding to the minimal pumping energy. The regulation is to be avoided when the pumping head is higher and the regulation is recommended when the pumping head is lower than the pressure corresponding to point O.

Although the regulation of water discharge using regulating valves can lead to higher energy efficiency of the heating system when the nominal pumping head is lower than the optimal value, this procedure have the followed disadvantages:

– an increased wear of regulating valves shutting elements;

– noise, vibration and hydraulic impacts with negative effects in the system;

– low operation reliability of the pumps.

The best procedure to obtain variable heat flow is the use of variable rotation speed pumps. The flow regulation (Fig. 5) is done due to the changing of the pump characteristic curve H (at different rotation speed n_1 and n_2) on the fixed characteristic curve of the system H_r. The operation point F_2 corresponds to the reduced pumping head H_{F2}.

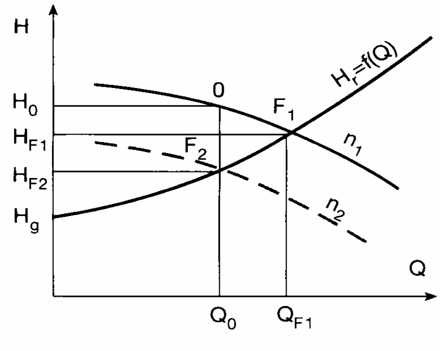

Fig. 5 Variable speed centrifugal pump operation

The characteristics of the pumps variable rotation speed could be expressed with the followed similitude relations:

$$\frac{Q_1}{Q_2}=\frac{n_1}{n_2} \quad (1)$$

$$\frac{H_1}{H_2}=\left(\frac{n_1}{n_2}\right)^2 \quad (2)$$

$$\frac{P_1}{P_2}=\left(\frac{n_1}{n_2}\right)^3 \quad (3)$$

The power demand P, in kW, at certain rotation speed is given by:

$$P=\frac{\gamma Q H_p}{1000\eta}=3600 w_p Q \quad (4)$$

where: γ is the specific weight of the water, in N/m^3; Q – the pumping discharge, in m^3/s; H_p – the pumping head corresponding to the operation point, in m; η – the global efficiency of the pumping plant; w_p – the specific pumping energy, in kWh/m^3.

The efficiency dependence of the rotation speed is given by the relation (5), thus, one can determine the efficiency η_2 in operation point F_2 according to the rotation speed n_2 in function of η_1 and n_1.

$$\eta_2=1-(1-\eta_1)\left(\frac{n_1}{n_2}\right)^{0,1} \quad (5)$$

In fact, at the majority of the pumps and especially at the big ones, the efficiency variation can be neglected for a variation of rotational speed of 1/3 from the nominal value.

In Figure 6 are presented the variation curves of H, Q, P and η for centrifugal pumps depending on rotational speed n. It can be observed that a reduction with 20 % of the rotational speed will lead to the reduction of power demand with 50 %, at constant pump efficiency. Thus, results the possibility to reduce the pumping energy consumption by using variable rotational speed pumps. One of possible ways to achieve is variable frequency drives (VFDs).

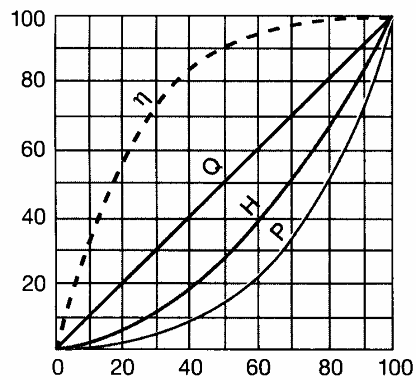

Fig. 6 Variation of centrifugal pump parameters with load

In certain countries, the use of the electronically driving methods of electrical engines the variation of rotation speed was extended up to industrial scale [1]. The variation of rotational speed of the electric driven pumps can be carried out with: frequency converters or variable frequency drives (VFDs), continuous current engines, voltage control and mechanical drives.

3. Throttling control valve versus variable speed drive for flow control

3.1 Comparative energy analysis of the adjustment process

The energy efficiency of the above presented regulation methods are analyzed based on the operation regime of a pump for different values of the rotation speed (Fig. 7).

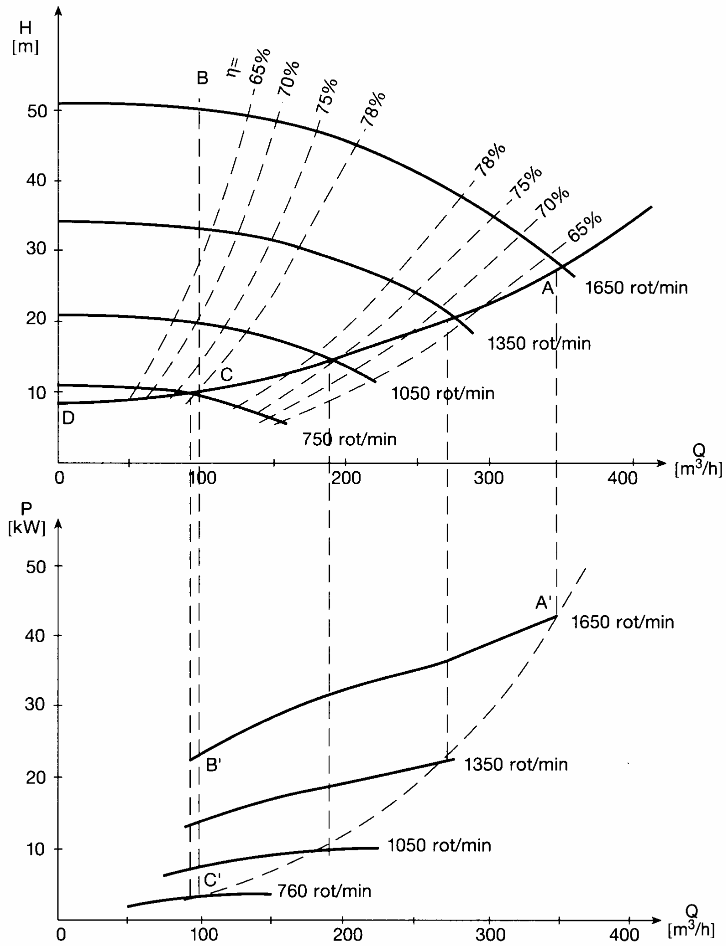

Fig. 7 Energy consumption for different flow with VFDs

If the maximal load is 350 m^3/h at the pumping head of 28 m, the absorbed power is 42,5 kW. If the water discharge is reduced to flow rate of 100m^3/h using throttling valve, the pumping head increases up to 50 m and the shaft power will be 23 kW at a constant rotational speed of 1650 rot/min. The operating curves are marked with A-B on the *H*-*Q* and with A’-B’ on the power diagram.

The relation with the shaft absorbed power is presented with the dashed curve. Thus, it is possible to compare the absorbed power, in the case of adjust with valves and with variable rotational speed pumps. Consequently, if the yearly distribution is known the energy consumption can be determined.

The numerical results, based on the characteristic curves from Figure 7, are presented in Table 1.

From the results of the analysis, it can be seen a yearly energy consumption decrease from 275064 kWh to 124173 kWh, by rotational speed variation. The energy saving is about 151000 kWh which represents about 55 %.

Table 1

The absorbed power and the energy consumption using adjusting valves and rotational speed variation

Discharge	Distribution		Regulating valves		Variable speed	
Q [m^3/h]	%	Hours	Power P [kW]	Energy W [kWh]	Power P [kW]	Energy W [kWh]
0	1	2	3	4	5	6
350	5	438	42,5	18615	42,5	18614
300	15	1314	38,5	50589	29,0	38106
250	20	1752	35,0	61320	18,5	32412
200	20	1752	31,5	55188	10,0	17520
150	20	1752	28,0	49056	6,5	11388
100	20	1752	23,0	40296	3,5	6132
Total	100	8760	–	275064	–	124173

3.2 Prediction of energy savings with variable speed drives in a heating station

The heating stations from Timisoara are being modernized in order to increase their efficiency and to be less harmful to the environment. Before this modernization be accomplished, the operation of one pump used in heat supply period was analyzed.

The measured parameters of the pump were: hot water flow rate Q and water pressure. The measurements were made every hour, during several days in a month with large variations in flow of hot water, April. Knowing water temperature, for every hour were calculated the power requirements in two cases: throttle control with a valve and reducing rotational speed with variable frequency drives.

The characteristics of the pomp are: type: TD 500-400-750; flow rate: 3150m^3/h; pumping head: 70m. The engine characteristics are: type: MIB-X 710Y; power: 800 kW; rated current: 94A; Voltage: 6000 V; rotational speed: 995 revolutions per minute-rpm; cosφ= 0.87; mass: 6000 kg.

Heat flow depends on the temperature of external air and is influenced by the temperature of the reverse network. The operational water flux of the pump was lower of course than the nominal one, for which the pump was built. In order to achieve the desired flow rate, as provided in the chart control it was necessary to act to close the valve mounted on the pump outlet. Thus reducing the water flow, the head of the pump becomes higher than that from characteristic curves at the same flow. In Figure 8 are presented characteristic curves for that type of pump: H=f(Q); η=f(Q); P=f(Q).The power absorbed by the electric engine is also lower. For each hour, authors calculated necessary power P_t for this case of throttle control of the network, with relation (4).

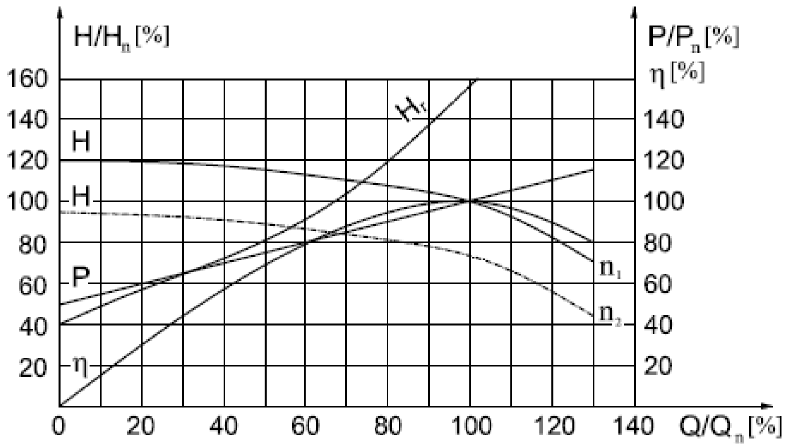

Fig. 8 Characteristic curves of the pump

For each day the authors calculated also the daily power used. The pump necessary power P_2, when the motor use frequency convertor, is obtained from affinity laws (1) and (3):

$$P_2 = P_1 \cdot \left(\frac{Q_2}{Q_1}\right)^3 \tag{6}$$

in which: P_1 is the necessary power of fixed speed pump for operating point Q_1 = 3150 m^3/h and H_1 =70 m.

The relationship between rotation speed of the pump and electric energy frequency is:

$$n = \frac{60 \cdot \nu}{p}$$

where: n is the rotational speed; ν-energy frequency; p-number of pole pairs of the engine.

If is necessary to change rotational speed, could be changed number of pole pairs of the engine or energy frequency. The second case is easily achievable.

In Figure 9 are plotted P_1, P_t and P_2 for the whole operating period from April. The average ratio between P_2 and P_t is 0.67. This means a reduction of electric energy applying adjustment method by variable rotational speed using VFDs compared with throttling valve control of 32.8%, i.e. 2835.2 kWh.

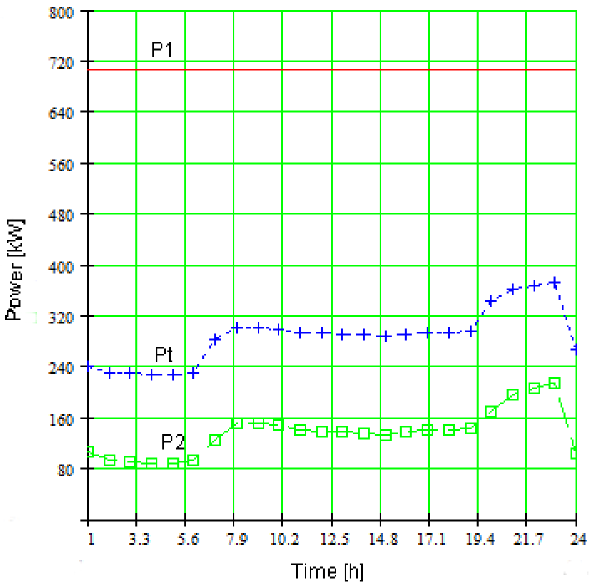

Fig. 9 Power consumption for different djustment methods

4. Economical aspects

The practice has shown that the investment cost of the auxiliary equipments for the maintenance of the safety of the variable rotation speed pumps represents about 10 % of the total exploiting costs. Thus, 90 % represents the energy consumption for the total exploiting period, which is approximately 15…20 years. At the same time, the obtained energy saving, using variable rotational speed pumps, will lead to a shorter recovery time of the investment costs.

In a power station operate dozens of pumps which power consumption is about 35% of its domestic consumption. Taking into account that domestic consume of a power station is about 10,000 kW, energy consumption of pumps 3,500 kW. Considering energy saved by using variable rotational speed compared with throttle control of 33%, for yearly operational time during winter 4,000 hours, could be saved 4,480,000 kWh. This could reduce the financial burden with about 500,000 dollars every year.

5. Conclusions

The water flow adjustment with variable rotation speed pumps is an advantageous optimization method of water pumping in urban heating stations, assuring the correlation between the heat demand and water discharge and obtaining, at the same time, important energy saving which can reach, under certain condition, even 60 %.

Using the rotation speed variation, the water pressure meet continuously to the required values, obtaining an important reduction of water losses in the system. At the same time, the high values of the pressure, which can lead to operation defects of the system equipments, are avoided.

Using frequency converters, the rotation speed of the power driven pumps can be increased, obtaining higher values than 50 Hz. Thus, the pumping capacity increases too. In this cases the lower capacity of a pumping station can increases, using frequency converters, replacing the engines with other with higher power.

For variation of the rotation speed the frequency converters represents the best solution, because these should be connected between the engine and the power source and set for the specific requirements. VFDs offer energy savings and a soft-starting capability. The voltage fluctuations that can occur in starting up large motors are also reduced. As reducing water flow by VFDs reduces head, pump and auxiliary wear and reduced. Motor shaft requirements decreases with cube of pump's rotational speed and this could life cycle costs of engine-pump assembly.

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Cercetari experimentale privind utilizarea adaosurilor de zgura granulata de furnal in beton. Cercetari experimentale pentru determinarea caracteristicilor de rezistenta si durabilitate a betoanelor preparate cu cimenturi tip II/A-S, III/A si respectiv cu ciment tip I si adaosuri de 10% si 37% zgura. Partea 2

Experimental researches on the use of granulated blast furnace slag additives in concrete. Experimental researches to determine the strength and durability characteristics of concretes prepared with cement type II / A-S, III / A and type I cement and of 10% and 37% slag additives. Part 2

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Rezumat: *Lucrarea prezinta rezultatele unor incercari de laborator desfasurate la UTCB pentru determinarea si compararea valorilor unor caracteristici de rezistenta si durabilitate a betoanelor preparate cu cimenturi tip II/A-S, III/A si respectiv cu ciment tip I si adaosuri de 10% si 37% zgura.*
In prima parte a articolului s-au prezentat baza teoretica si determinarile experimentale care trebuie efectuate in vederea calcularii coeficientului k, care indica contributia adaosurilor de zgura din betoane pentru obtinerea unei rezistente echivalente cu cea a unui beton fara adaosuri.

Cuvinte cheie: beton, adaos, zgura, rezistenta, durabilitate

Abstract: *This paper presents the results of laboratory tests performed on UTCB for determining and comparing the values of strength and durability characteristics of concretes prepared with cement type II / A-S, III / A and Type I cement and 10% and 37% slag. In the first part of the article were presented the theoretical and experimental determinations to be carried out to calculate the coefficient k, which indicates the contribution of slag additives to achieve an equivalent strength to that of concrete without additives.*

Key words: concrete, additive, slag, strength, durability

1. Introducere

Aceasta lucrare prezinta rezultatele cercetarilor experimentale privind utilizarea adaosurilor de zgura granulata de furnal in betoane, din perspectiva viitoarelor modificari ale standardului EN 206-1, efectuate pentru determinarea caracteristicilor de rezistenta si durabilitate a betoanelor preparate cu cimenturi tip II/A-S, III/A si respectiv cu ciment tip I si adaosuri de 10% si 37% zgura.

Prima parte a articolului a avut ca obiectiv principal prezentarea modalitatilor de determinare experimentala a coeficientului k, care reprezinta o etapa importanta pentru determinarea performantelor echivalente ale betonului in cazul utilizarii adaosurilor in betoane.

In aceasta parte sunt prezentate valorile unor caracteristici de rezistenta si de durabilitate determinate experimental, pe baza compozitiilor realizate prin considerarea coeficientului k=0,5, asa cum a rezultat din rezultatele cercetarilor experimentale efectuate prezentate in prima parte a articolului. Au fost proiectate compozitii ale betoanelor in vederea obtinerii a trei clase de betoane C16/20, C25/30a si C30/37a (ultimele doua compozitii cu aer antrenat).

Compozitiile au inclus cimenturi de tip CEM I 42,5R cu adaosuri de zgura in beton de 10% respectiv 37% si respectiv betoane preparate cu cimenturi cu adaosuri de zgura in aceleasi proportii CEM II/A-S 42,5R, respectiv CEM III/A 42,5N-LH.

Clasa de beton C 16/20

- S-au preparat betoane cu ciment tip CEM II/ A–S 42,5R (10% zgura) cu dozaj de ciment de 260 kg/m^3, raport A/C = 0,65
- S-au preparat betoane cu adaosuri de zgura de 10% (k=0,5)

c_1 +0,5 • 0,1 c_1 = 260 kg/m^3; c_1 = 248 kg/m^3

zgura = 24,8 kg/m^3

- S-au preparat betoane cu ciment CEM III/ A 42,5 N-LH (37% zgura), dozaj 260 kg/m^3
- S-au preparat betoane cu adaos de zgura de 37%

c_2 +0,5 • 0,37 c_2 = 260 kg/m^3 ; c_2 = 219 kg/m^3

zgura = 81 kg/m^2

S-au efectuat cercetari experimentale pentru cele 4 amestecuri pentru determinarea:

- Rapoartelor A/C
- Absorbtiei, porozitatii;
- Permeabilitatii;
- Rezistentei la compresiune;
- Carbonatarii.

Clasa de beton C25/30

- S-au preparat betoane cu ciment tip CEM II/A-S 42,5R (10% zgura) cu dozaj ≥ 300 kg/m^3, se propune 330 kg/m^3;
- S-au preparat betoane cu adaosuri de zgura 10%

$c_1 + 0{,}5 \bullet 0{,}1\ c_1 = 330$ kg/m^3 ; $c_1 = 314$ kg/m^3

zgura = 31,41 kg/m^2

- S-au preparat betoane cu ciment CEM III/A 42,5N-LH (37%)
- S-au preparat betoane cu adaosuri de zgura 37%

$c_2 + 0{,}5 \bullet 0{,}37\ c_2 = 330$ kg/m^3 ; $c_2 = 278$ kg/m^3

zgura = 103 kg/m^2

Pentru cele patru amestecuri s-au determinat:

- Rapoartele A/C;
- Absorbtia, porozitatea;
- Permeabilitatea;
- Rezistenta la compresiune;
- Carbonatarea;
- Rezistenta la inghet-dezghet.

Clasa de beton C 30/37

- S-au preparat betoane cu ciment CEM II/ A-S 42,5 R (10% zgura) cu dozaj de 360 kg/m^3
- S-au preparat betoane cu adaos de zgura in proportie de 10%

$c_1 + 0{,}5 \bullet 0{,}1\ c_1 = 360$ kg/m^3 ; $c_1 = 343$ kg/m^3

zgura = 34,3 kg/m^2

- S-au preparat betoane cu ciment CEM III/A 42,5 N-LH, dozaj 360 kg/m^3
- S-au preparat betoane cu adaos de zgura de 37%

$c_2 + 0{,}5 \bullet 0{,}37\ c_2 = 360$ kg/m^3 ; $c_2 = 304$ kg/m^3

zgura = 112,5 kg/m^3

Pentru cele patru amestecuri s-au determinat:

- Rapoartele A/C;
- Absorbtia, porozitatea;
- Permeabilitatea;
- Rezistenta la compresiune;
- Carbonatarea;
- Rezistenta la inghet-dezghet;
- Rezistenta la atac sulfatic.

S-a urmarit in mod special compararea rezultatelor obtinute pentru betoanele cu adaosuri de zgura, respectiv preparate cu cimenturi cu adaosuri de zgura la proportii egale de adaosuri si la acelasi raport A/C echivalent (Apa+aditiv)/(ciment+0.5zgura).

2. Rezultate obtinute
2.1. Clasa de beton prescrisa C16/20

In tabelul 1 se prezinta compozitiile utilizate la prepararea betonului la un raport A/C echivalent de 0.65.

Tabelul 1

Compozitiile si caracteristicile betoanelor preparate cu un raport A/C echivalent de 0.65

Tip ciment	Dozaj ciment (kg/m^3)	Dozaj zgura (kg/m^3)	Apa (l)	Aditiv Glenium (l)	Agregate (kg)	sort 0-4	sort 4-8	sort 8-16	Tasare (mm)	Densitate (kg/m^3)
I 42										
886	248	24.8	166.43	2.57	1908.17	763.27	381.63	763.27	195	2361
887	219	81.0	166.17	2.83	1884.15	753.66	376.83	753.66	155	2372
II/A-S										
885	260	0	166.55	2.45	1919.48	767.79	383.90	767.79	200	2338
III/A										
899	260	0	166.55	2.45	1919.48	767.79	383.90	767.79	200	2369

In tabelul 2, se indica rezultatele obtinute pentru rezistenta la compresiune la diferite termene. Probele au fost mentinute in apa pana la 2 si respectiv 28 de zile. In cazul incercarilor la 90 de zile, probele au fost mentinute in apa pana la varsta de 7 zile apoi in conditii standardizate de temperatura si umiditate.

Tabelul 2

Valorile rezistentelor la compresiune ale betoanelor preparate cu un raport A/C echivalent =0.65

Serie/ Tip CEM	Dozaj ciment (kg/m^3)	Dozaj zgura (kg/m^3)	Rezistenta la compresiune (N/mmp)						f_{cm2}/ f_{cm28}
			2 zile		28 zile		90 zile		
886/ I	248	24.8	18.07	18.50	30.16	30.16	42.80	40.73	0.61
			19.40		29.84		39.00		
			18.03		30.48		40.40		
887/I	219	81	17.32	17.43	28.14	27.76	37.54	37.81	0.63
			17.29		28.64		38.90		
			17.67		26.49		37.00		
885/II	260	0	16.74	16.77	27.40	28.81	34.18	35.13	0.58
			16.39		29.44		36.16		
			17.18		29.60		35.04		
899/III	260	0	12.18	11.83	25.38	26.31	30.18	30.53	0.45
			12.22		26.85		29.68		
			11.08		26.70		31.72		

La 28 de zile de la turnare, valorile obtinute pentru rezistenta la compresiune nu indica diferente semnificative intre rezistentele betonului la aceleasi dozaje de zgura in ciment si respectiv in beton. Toate compozitiile de betoane indica realizarea clasei C16/20.

Dupa 90 de zile de la turnare, betoanele preparate cu adaos de zgura au rezistente mai mari cu aprox. 5 N/mm^2 comparativ cu betoanele preparate cu cimenturi cu dozaj de 260 kg/m^3.

Raportul rezistentelor medii la compresiune la 2 si respectiv 28 de zile indica cresteri rapide pentru betoanele preparate cu CEM I si adaos de zgura si respectiv cu CEM II/A-S. In cazul betoanelor preparate cu CEM III, evolutia rezistentelor este medie.

Valorile porozitatii, absorbtiei si permeabilitatii, obtinute la 28 de zile pentru probe de beton mentinute 7 zile in apa, apoi pana la efectuarea testelor in conditii standardizate de temperatura si umiditate, sunt prezentate in tabelul 3. Probele pentru determinarea porozitatii au fost uscate si apoi au fost imersate in apa pana la obtinerea unei mase constante.

Tabelul 3

Valorile obtinute pentru porozitate, absorbtie si permeabilitate

Seria/ CEM	Dozaj ciment (kg/m^3)	Dozaj zgura (kg/m^3)	Porozitate, masă const., %		Absorbție, masă const., %		Adâncime de patrundere a apei, cm	
			val.indiv.	val.medie	val.indiv	val.medie	val.indiv.max	val.medie
886/ I	248	24.8	5.84	5.80	2.56	2.55	2.05	2.10
			5.93		2.62		2.52	
			5.63		2.46		1.73	
887/I	219	81	5.84	5.69	2.53	2.46	2.31	2.30
			5.51		2.39		2.39	
			5.72		2.46		2.19	
885/II	260	0	6.01	6.25	2.69	2.81	2.09	2.18
			6.28		2.82		2.25	
			6.46		2.91		2.20	
899/III	260	0	7.76	8.30	3.58	3.86	1.57	1.67
			8.23		3.83		1.81	
			8.92		4.16		1.62	

In ceea ce priveste absorbtiile, si in acest caz valorile sunt relativ apropiate, rezultate mai mari inregistrandu-se in cazul betonului preparat cu cimentul CEM III/A.

Probele de beton utilizate pentru determinarea permeabilitatii au fost expuse unei presiuni de 5 barr, valorile obtinute pentru adancimea de patrundere a apei fiind sub 2.5 cm. Cea mai mica valoare a adancimii de patrundere a fost obtinuta pentru betoanele preparate cu CEM III/A, celelalte tipuri de betoane avand valori comparative.

Probele utilizate pentru determinarea adancimii de carbonatare au fost mentinute 7 zile in apa si apoi in conditii standardizate de laborator pana la data incercarii. Pentru determinarea adancimii de carbonatare in conditii accelerate, probele au fost expuse 72 de ore la o concentratie de CO_2 de 0.2 MPa, in conformitate cu SR 13379 [1].

Tabelul 4

Valorile obtinute pentru adancimea de carbonatare a betoanelor in conditii de laborator si respectiv in conditii accelerate

Seria/ CEM	Dozaj ciment (kg/m³)	Dozaj zgura (kg/m³)	Conditii laborator 90 zile /7 zile apă				Conditii accelerate 28 zile/7 zile apă			
			val.indiv. medie	val. medie	val.indiv. max	val. medie	val.indiv. medie	val.medie	val.indiv. max	val.medie
886/ I	248	24.8	1.10		3.17		3.22		5.90	
			1.60		2.97	3.12	3.23	3.19	5.22	5.35
			0.90	1.20	3.23		3.11		4.92	
887/ I	219	81	1.90		4.69		3.00		5.87	
			1.18		3.73	3.98	4.67	3.63	6.67	5.55
			1.21	1.43	3.51		3.21		4.11	
885/ II	260	0	0.80		3.04		2.73		5.86	
			1.10	0.89	4.18	3.73	2.11	2.28	4.23	5.18
			0.78		3.96		2.01		5.45	
899/ III	260	0	5.10		6.99		20.48		35.02	
			5.64	5.36	7.88	8.15	19.34	19.13	30.56	31.68
			5.35		9.58		17.56		29.45	

In cazul acestei compozitii realizate cu CEM III/A s-au inregistrat, de altfel, valori mai mari si pentru carbonatarea in conditii normale de mentinere sau in conditiile carbonatarii accelerate (Tabelul 4). Evolutia rezistentei betoanelor preparate cu CEM III/A de la 28 la 90 de zile a fost, de asemenea, redusa.

2.2. Clasa de beton prescrisa C25/30a

Compozitiile betoanelor pentru clasa C25/30a sunt prezentate in tabelul 5. De remarcat este procentul mare de aer antrenat obtinut in cazul betoanelor preparate cu adaos de zgura.

Tabelul 5

Compozitiile si caracteristicile betoanelor preparate cu un raport A/C echivalent de 0.5

Tip ciment	Dozaj ciment (kg/m³)	Dozaj zgura (kg/m³)	Apa (l)	Aditiv Glenium (l)	Aditiv Microair (l)	Agregate (kg)	sort 0-4	sort 4-8	sort 8-16	Diametru (mm)	Tasare (mm)	Densitate (kg/m³)	Aer (%)
I 42													
889	314	31.41	161.05	3.26	0.691	1856.47	742.59	371.29	742.59		210	2192	10
890	278	103.0	160.65	3.59	0.762	1825.21	730.08	365.04	730.08		210	2151	10
II/A-S													
888	330	0	161.23	3.11	0.66	1869.99	748.00	374.00	748.00		205	2180	9.2
III/A													
897	330	0	161.23	3.11	0.66	1869.99	748.00	374.00	748.00	457	235	2235	8.9

Rezultatele inregistrate pentru rezistenta la compresiune (tabelul 6) indica o usoara diferenta intre rezistenta la 28 de zile inregistrata in cazul betonului cu adaos de zgura de 37% fata de betonul preparat cu cimentul CEM III/A.

Tabelul 6

Valorile rezistentei la compresiune obtinute pentru betoane preparate cu A/C echivalent de 0.5

Serie/ Tip CEM	Dozaj ciment (kg/m^3)	Dozaj zgura (kg/m^3)	Rezistenta la compresiune (N/mm^2)						f_{cm2}/ f_{cm28}
			2 zile		28 zile		90 zile		
889/ I	314	31.41	19.07	18.45	26.92	26.49	33.32	32.55	0.70
			18.15		26.57		32.22		
			18.14		25.97		32.10		
890/I	278	103.0	18.36	18.10	28.51	26.86	33.56	33.68	0.67
			18.09		25.99		32.56		
			17.84		26.08		34.92		
888/II	330	0	18.32	17.95	25.18	25.84	32.45	30.51	0.69
			18.17		26.86		30.94		
			17.35		25.47		28.15		
897/III	330	0	12.72	13.14	30.23	30.69	30.23	34.01	0.43
			13.29		31.01		35.86		
			13.40		30.84		35.95		

Se observa, de asemenea, ca in cazul betoanelor cu 37% zgura raportul A/C de 0.5 nu a fost suficient pentru atingerea clasei de C25/30.

Tabelul 7

Valorile obtinute pentru porozitate, absorbtie si permeabilitate la varsta de 28 de zile

Seria/ CEM	Dozaj ciment (kg/m^3)	Dozaj zgura (kg/m^3)	Porozitate, masă const., %		Absorbție, masă const., %		Adâncime de patrundere a apei, cm	
			val.indiv.	val.medie	val.indiv	val.medie	val.indiv.max	val.medie
889/ I	314	31.41	6.93	7.26	3.27	3.42	2.01	2.00
			7.53		3.55		2.02	
			7.32		3.45		1.98	
890/I	278	103	6.22	6.41	2.90	3.01	2.00	1.97
			6.55		3.07		1.98	
			6.46		3.05		1.94	
888/II	330	0	6.81	6.81	3.22	3.22	1.99	2.19
			6.90		3.23		1.63	
			6.73		3.20		2.96	
897/III	330	0	7.32	7.96	3.37	3.69	1.83	1.72
			8.53		3.99		1.87	
			8.03		3.72		1.46	

Valorile absorbtiei si porozitatii sunt comparabile pentru betoanele cu adaosuri respectiv pentru cele preparate cu cimenturi cu adaosuri (tabelul 7), iar in cazul grosimii stratului carbonatat si in acest caz se inregistreaza valori mai mari in cazul betonului preparat cu cimentul CEM III/A, atat in conditii de mentinere de laborator, cat si in conditii de carbonatare accelerata (tabelul 8).

Tabelul 8

Valorile obtinute pentru adancimea de carbonatare a betoanelor mentinute in conditii de laborator

Seria/ CEM	Dozaj ciment (kg/m³)	Dozaj zgura (kg/m³)	90 zile /7 zile apă		90 /7 zile apă		CA 28 zile/7 zile apă		CA 28 zile/7 zile apă	
			val.indiv. medie	val. medie	val.indiv. max	val. medie	val.indiv. medie	val. medie	val.indiv. max	val. medie
889/ I	314	31.41	3.23	3.33	4.67	4.70	7.21	6.65	9.70	8.69
			3.91		5.32		6.28		7.55	
			2.86		4.12		6.45		8.82	
890/I	278	103	4.23	3.74	5.67	5.23	5.20	5.29	8.75	8.40
			3.21		5.12		5.37		8.46	
			3.78		4.89		5.29		7.98	
888/II	330	0	0.80	0.70	2.80	2.95	4.24	4.91	9.50	8.98
			0.73		3.10		5.72		8.11	
			0.56		2.95		4.78		9.34	
897/III	330	0	4.38	3.81	5.22	5.35	8.64	10.30	12.69	15.32
			3.42		5.48		10.87		16.18	
			3.64		5.35		11.39		17.10	

De remarcat valorile mai reduse ale adancimii de carbonatare obtinute pentru betoanele preparate cu CEM II/A-S.

2.3. Clasa de beton prescrisa C30/37a

In tabelul 9 se prezinta compozitiile betoanelor pentru aceasta clasa prescrisa de beton.

Tabelul 9

Compozitiile si caracteristicile betoanelor proaspete preparate cu un raport A/C echivalent = 0.5

Tip ciment	Dozaj ciment (kg/m³)	Dozaj zgura (kg/m³)	Apa (l)	Aditiv Glenium (l)	Aditiv Microair (l)	Agregate (kg)	sort 0-4	sort 4-8	sort 8-16	Diametru (mm)	Tasare (mm)	Densitate (kg/m³)	Aer (%)
I 42													
892	343	34.30	175.69	3.56	0.75	1788.72	715.49	357.74	715.49	550	245	2333	6.7
893	304	112.5	175.24	3.93	0.83	1754.30	701.72	350.86	701.72	490	225	2269	7.3
II/A-S													
891	360	0	175.88	3.40	0.72	1803.92	721.57	360.78	721.57		200	2344	4.4
III/A													
898	360	0	175.88	3.40	0.72	1803.92	721.57	360.78	721.57	445	220	2401	4

Procentul de aer antrenat obtinut in cazul betoanelor preparate cu zgura este mai mare decat cel obtinut in cazul betoanelor preparate fara adaos de zgura.

Rezistentele la compresiune prezentate in tabelul 10 indica de aceasta data diferente intre valorile obtinute pentru betoanele preparate cu cimenturile cu adaosuri si respectiv cu adaosul in betoane. Rezultatele indica valori superioare in cazul betoanelor preparate cu cimenturile de tip CEM II/A-S si CEM III/A. De altfel, numai betoanele preparate cu cimentul de tip CEM III/A si respectiv II/A-S au realizat clasa prescrisa a betonului.

Tabelul 10

Valorile rezistentei la compresiune ale betoanelor preparate cu A/C echivalent = 0.5

Serie/ Tip CEM	Dozaj ciment (kg/m³)	Dozaj zgura (kg/m³)	Rezistenta la compresiune (N/mmp)						f_{cm2}/f_{cm28}
			2 zile		28 zile		90 zile		
892/ I	343	34.3	16.41	17.20	29.34	30.11	39.58	38.23	0.57
			16.92		30.16		36.89		
			18.26		30.82		38.21		
893/I	304	112.5	21.64	20.82	38.08	37.07	40.23	40.47	0.56
			20.32		36.25		40.91		
			20.51		36.88		40.28		
891/II	360	0	26.06	25.54	40.18	40.10	45.25	45.00	0.64
			26.26		40.20		41.15		
			24.31		39.92		48.60		
898/III	360	0	20.64	19.63	43.80	44.55	44.50	46.44	0.44
			19.41		44.96		47.69		
			18.84		44.90		47.14		

In ceea ce priveste valorile absorbtiei, acestea sunt comparabile intre cele doua tipuri de betoane, dar si in acest caz valorile inferioare (aspect favorabil) au fost obtinute pentru betoanele preparate cu cimenturile de tip CEM II A-S si CEM III/ A (tabelul 11).

Tabelul 11

Valorile obtinute pentru porozitate, absorbtie, permeabilitate la 28 de zile

Seria/ CEM	Dozaj ciment (kg/m³)	Dozaj zgura (kg/m³)	Porozitate, masă const., %		Absorbție, masă const., %		Adâncime de patrundere a apei, cm	
			val.indiv.	val.medie	val.indiv	val.medie	val.indiv.max	val.medie
892/ I	343	34.3	6.87	7.01	3.16	3.23	2.84	2.70
			7.11		3.29		2.44	
			7.05		3.23		2.82	
893/I	304	112.5	6.52	6.63	2.95	3.02	2.57	2.41
			6.61		3.01		2.33	
			6.76		3.1		2.34	
891/II	360	0	5.69	5.75	2.52	2.54	1.64	1.58
			5.69		2.50		1.27	
			5.87		2.59		1.83	
898/III	360	0	10.16	9.03	4.51	3.95	1.44	1.38
			9.72		4.25		1.33	
			7.20		3.10		1.38	

In Tabelul 12 se prezinta rezultatele obtinute pentru adancimea de carbonatare.

Si in acest caz betonul preparat cu cimentul CEM III/A a prezentat cele mai mari adancimi ale stratului de beton carbonatat.

Tabelul 12

Adancimea de carbonatare a betoanelor preparate cu A/C echivalent = 0.5

Seria/ CEM	Dozaj ciment (kg/m³)	Dozaj zgura (kg/m³)	90 zile /7 zile apă		90zile /7 zile apă		CA 28 zile/7 zile apă		CA 28 zile/7 zile apă	
			val.indiv. medie	val.medie	val.indiv. max	val.medie	val.indiv. medie	val.medie	val.indiv. max	val.medie
892/ I	343	34.3	2.50	2.92	3.11	3.92	5.94	5.46	9.12	9.20
			3.26		4.57		4.47		8.53	
			3.00		4.08		5.96		9.95	
893/I	304	112.5	3.29	3.62	4.34	4.72	6.66	7.35	12.54	13.48
			4.12		5.14		7.39		12.60	
			3.45		4.69		7.99		15.31	
891/II	360	0	0.41	0.98	2.98	3.56	5.44	4.67	9.91	8.23
			1.44		4.42		4.80		7.66	
			1.10		3.28		3.77		7.11	
898/III	360	0	3.70	3.58	4.38	4.99	6.40	6.93	11.91	12.77
			3.43		4.88		7.93		14.06	
			3.62		5.71		6.46		12.34	

S-au obtinut valori ale adancimii de carbonatare asemanatoare pentru betoanele preparate cu 10% zgura si respectiv betoanele preparate cu ciment cu 10% zgura pentru probe expuse la carbonatare accelerata.

Valorile cele mai mici ale adancimii de carbonatare pentru probe expuse in conditii de laborator au fost obtinute pentru betoanele preparate cu CEM II/A-S.

3. Concluzii

Cercetarile experimentale efectuate au condus la urmatoarele concluzii:

3.1. Compararea valorilor unor caracteristici de rezistenta si durabilitate ale betoanelor preparate cu cimenturi cu adaosuri respectiv cu adaosuri in aceleasi proportii in betoane au scos in evidenta depedenta acestora de compozitie (dozaj liant).

3.2. Rezistentele la compresiune nu au prezentat diferente importante intre cele doua categorii de betoane la dozajele mai mici de 330 kg/m^3. La dozajele mai mari (de exemplu peste 360 kg/m^3) s-au obtinut rezistente mai mari pentru betoanele preparate cu cimenturile cu adaosuri. Evident rezultatele obtinute sunt dependente de rezistentele cimenturilor utilizate.

3.3. Valorile absorbtiei si porozitatii au fost comparabile pentru categoriile de betoane analizate fiind mai reduse cu scaderea raportului A/C in ambele cazuri.

3.4. Adancimile de carbonatare ale betoanelor, determinate in conditii de mentinere in laborator, respectiv accelerate, au indicat in general valori comparabile, ceva mai mari in cazul betoanelor cu cimenturi cu adaosuri de tip CEM III.

3.5. Rezultatele inregistrate indica faptul ca determinarea experimentala a coeficientului k (prezentata in prima parte a articolului) este o conditie esentiala in aplicarea conceptului de performanta echivalenta a betonului, dar trebuie completata cu incercari specifice pentru determinarea unor caracteristici de rezistenta si durabilitate ale betonului, fapt ce reiese, de altfel cu claritate, atat din prevederile proiectului de revizuire a standardului EN 206 [2], cat si din rezultatele cercetarilor experimentale.

Bibliografie

[1] SR 13379: 2007 – Betoane si mortare de ciment. Estimarea penetrarii accelerate a dioxidului de carbon

[2] prEN206: 2012 - Beton. Partea 1: Specificație, performanță, producție şi conformitate.