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Research Article

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Prediction of Some Properties of Retempered Concrete in Hot Weather

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Abstract

This paper present statistical study to proposed empirical equations to predicting some properties of the fresh concrete (additional water for first and second retempering, final slump and dry unit weight), also some properties of the hardened concrete (compressive, flexural, split tensile strength and modulus of elasticity) depending on the simple properties of the retempered concrete mix (water cement ratio, temperature, air content, humidity, mix proportion and unit weight). Theoretical results obtained from these proposed equations found to be in good agreement with the experimental data found in literature.

Keywords: Retempering; Concrete mixes; Fresh concrete properties; Hot weather concrete

Introduction

Using and placing concrete during the hot summer months present far different challenges than use and placement during cold weather. The summer month effects of temperature, wind, and air humidity can all have a negative impact on the performance of concrete. For purposes of concrete use and placement, "hot weather" can be defined as any period of high temperature during which special precautions need to be taken to ensure proper handling, placing, finishing and curing of concrete. Hot weather problems are most frequently encountered in the summer, but critical drying factors such as high winds and dry air can occur at any time, especially in arid or tropical climates.

Higher temperatures cause water to evaporate from the surface of the concrete at a much faster rate and cement hydration occurs more quickly, causing the concrete to stiffen earlier and improving the chances of plastic cracking occurring. Concrete cracking may result from rapid drops in the temperature of the concrete. This occurs when a concrete slab or wall is placed on a very hot day and which is immediately followed by a cool night. High temperature also accelerates cement hydration and contributes to the potential for cracking in massive concrete structures. Higher relative humidity tends to reduce the effects of high temperature.

Other hot weather problems include increased water demand, which raises the water-cement ratio and yield lower potential strength, accelerated slump loss that can cause loss of entrained air, fast setting times requiring more rapid finishing or just lost productivity. Environmental conditions and delays in the placement of concrete may cause loss in the workability of super-plasticized concrete. The loss can be restored by retempering with water or super-plasticizers. The use of water usually results in a reduction in strength. There is divergence of opinion on the engineering properties of the tempered concrete. The practice of retempering in hot-dry environments is frequently performed to increase slump beyond typical specification's limits (of 100 ± 25 mm) in order to cope with the need for expediting the casting operations and reducing the consolidation effort.

The strength of concrete of given mix proportions are very seriously affected by the degree of its compaction. Therefore that the consistence of the mix be such that the concrete can be transported, placed and finished sufficiently easily and without segregation. The concrete mix satisfying these conditions is said to be workable. However workability is measured by slump, compacting factor or flow test. Freshly mixed concrete stiffened with time, some of the water of the mix absorbed by the aggregate and some is lost by evaporation. Particularly if the concrete is exposed to sun or wind and some is removed by the initial chemical reactions. This loss of mix water lead to reduction in slump or compacting factor therefore reduction in workability of the concrete. Generally workability reduces with the time and increasing of temperature. Therefore it is apparent that on a hot day water content of the mix would have be increased for constant workability [1,2].

Loss of slump and the consequent reduction in workability with time is an inherent property of fresh concrete, this loss in workability is accelerated in hot climates. A delay in the discharge of concrete from a truck mixer, or a delay in the placement of concrete due to other reasons could cause stiffening to the point of unworkability. Therefore in actual field application in hot climate, it may be necessary to retemper the concrete to maintain the required workability. The process or procedure adopted in achieving the desired consistency of a given fresh concrete, already mixed to the specified consistency, by the addition of water, a super plasticizer or cement paste or any combination of these, is known as retempering [3].

Hanayneh and Itani [4] attempted to study the engineering properties of retempered concrete having different normal strengths. The slump, compressive strength, modulus of rupture, splitting strength, Poisson's ratio and the modulus of elasticity were determined. Alhozaimy [5], investigated the effect of retempering on the workability and strength of ready-mixed concrete (RMC) in hot-dry environments was investigated. This study covered 12 construction sites with concrete delivered by 11 different RMC suppliers. The results indicate that the reduction in strength due to water addition is proportional to the associated increase in slump. In cases where water was added to restore the slump to the specifications limits (100 ± 25 mm), the reduction of strength was below 10%. However, when water was added to increase slump beyond these limits, the reduction of strength may be as high as 35%. The study shows the change in slump can be used to predict reduction of strength due to jobsite water additions when practical considerations preclude accurate determination of the w/c ratio.

Erdogdu [6-8] used the super-plasticizer of ASTM C (494) Type F for retempering concrete to restore its initial slump. Concrete mixes having an initial slump of about 19 cm were prepared and subjected

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to prolonged mixing with different mixing duration such as 30 min, 60 min, 90 min, 120 min and 150 min following an initial mixing of 5 min to ensure homogeneity. At the end of each mixing period, cube specimens of 15 cm were cast from concrete retempered to its initial slump level and tested at the age of 28 days for compressive strength. Results revealed that compared to the concrete retempered with water, those retempered with a superplasticizer admixture have yielded significantly higher strength regardless of the mixing duration. This paper present a statistical study to proposed empirical equations to predicting some properties of the fresh and hardened concrete in term of simple properties of the retempered concrete mixes, theoretical results obtained from these proposed equations found to be in good agreement with the experimental data found in literature [3].

Analysis and Results

Method of multi-linear regression analysis is used to proposed different expressions to predicting some properties of the fresh and hardened concrete depending on the simple properties of the concrete mix, the general proposed equation take the following form:

$$Y = K_0 + K_1 \times X_1 + K_2 \times X_2 + K_3 \times X_3 + K_4 \times X_4 + K_5 \times X_5 + K_6 \times X_6 \quad (1)$$

where:

$(X_1, X_2, X_3, X_4, X_5 \; \& X_6)$ are independent variables.

$(K_0, K_1, K_2, K_3, K_4, K_5 \; \& \; K_6)$ are coefficients.

Values of these coefficients are determined by incorporation of experimental data and using computer program. Depending on the least square principle:

$$S = \sum_{1}^{N} (Y - y)^2 \quad (2)$$

where:

S = Sum of square of differences between calculated and experimental results.

y = Experimental value of the dependent variable.

Y = Calculated value of the dependent variable.

N = No. of observed points.

$$S = \sum_{1}^{N} (K_0 + K_1 * X_1 + K_2 * X_2 + K_3 * X_3 + K_4 * X_4 + K_5 * X_5 + K_6 * X_6 - y)^2 \quad (3)$$

To determine value of the coefficients, the error function (S) is minimized with respect to the coefficients:

$$\frac{\partial S}{\partial Ki} = 0 \quad (4)$$

where i = 1,2,3…6

These equations lead to generate a set of simultaneous equations as shown below, solved by using computer programs and incorporation of experimental data to determine the coefficients value for different cases.

$$[A]\{K\} = \{B\} \quad (5)$$

Where $[A]$ is the coefficient matrix.

$$\begin{bmatrix} N & \Sigma X_1 & \Sigma X_2 & \Sigma X_3 & \Sigma X_4 & \Sigma X_5 & \Sigma X_6 \\ \Sigma X_1 & \Sigma X_1^2 & \Sigma X_1X_2 & \Sigma X_1X_3 & \Sigma X_1X_4 & \Sigma X_1X_5 & \Sigma X_1X_5 \\ \Sigma X_2 & \Sigma X_2X_1 & \Sigma X_2^2 & \Sigma X_2X_3 & \Sigma X_2X_4 & \Sigma X_2X_5 & \Sigma X_2X_6 \\ \Sigma X_3 & \Sigma X_3X_1 & \Sigma X_3X_2 & \Sigma X_3^2 & \Sigma X_3X_4 & \Sigma X_3X_5 & \Sigma X_3X_6 \\ \Sigma X_4 & \Sigma X_4X_1 & \Sigma X_4X_2 & \Sigma X_4X_3 & \Sigma X_4^2 & \Sigma X_4X_5 & \Sigma X_4X_6 \\ \Sigma X_5 & \Sigma X_5X_1 & \Sigma X_5X_2 & \Sigma X_5X_3 & \Sigma X_5X_4 & \Sigma X_5^2 & \Sigma X_5X_6 \\ \Sigma X_6 & \Sigma X_6X_1 & \Sigma X_6X_2 & \Sigma X_6X_3 & \Sigma X_6X_4 & \Sigma X_6X_5 & \Sigma X_6^2 \end{bmatrix} \begin{Bmatrix} K_0 \\ K_1 \\ K_2 \\ K_3 \\ K_4 \\ K_5 \\ K_6 \end{Bmatrix} = \begin{Bmatrix} \Sigma Y \\ \Sigma X_1Y \\ \Sigma X_2Y \\ \Sigma X_3Y \\ \Sigma X_4Y \\ \Sigma X_5Y \\ \Sigma X_6Y \end{Bmatrix}$$

$$\{K\} = [A]^{-1}\{B\} \quad (6)$$

Properties of the fresh and hardened concrete determined for the mixes measured or tested before addition of water for retempering this stage is known as an initial stage (or first retempering), but approximately (30) minutes after the initial mixing additional water added to the concrete mix to increase the workability, this stage is known as a first retempering. Approximately one hour after the initial mixing. The second additional water is added to the concrete mix to keep workability constant; this stage is known as a second retempering. For all these stages properties of the fresh & hardened concrete are measured or tested.

All these properties of the fresh and hardened concrete relating with the selected independent variables, which represent the simple properties of the concrete mix. The independent variables $(X_1, X_2, X_3, X_4, X_5 \; \& X_6)$ are taken as the following form to represent the correct mix properties:

X_1 = Temperature (T)

X_2 = Water cement ratio (W/C)

$X_2 = \frac{C + w}{S + G}$

where: C, w, S and G are cement, water, sand and gravel proportions respectively.

X_4 = Air content % (A)

X_5 = Humidity % (H)

X_6 =Unit weight kg/m^3 (γ)

A computer program for developing such multi-linear regression analysis was adopted which yield the different equations by incorporation of experimental data found in literature [3]. The fresh and hardened concrete properties relating with the selected independent variables are shown in Tables 1a and 1b.

Fresh concrete

The following properties of the fresh concrete are taken as dependent variables to evaluate general empirical equations relating these properties with the independent variables $(X_1, X_2, X_3, X_4, X_5 \; \& X_6)$

Wd_{R1} = Water dosage for first retempering (kg).

Wd_{R2} = Water dosage for second retempering (kg).

S_f = Final slump (mm).

γ_D = Dry unit weight (kg/m^3) for initial stage.

γ_{DR1} = Dry unit weight (kg/m^3) for first retempering stage.

γ_{DR2} = Dry unit weight (kg/m^3) for second retempering stage.

V = Pulse velocity (m/sec) for initial stage.

V_{R2} = Pulse velocity (m/sec) for first stage.

V_{R2} = Pulse velocity (m/sec) for second stage.

S_L = Slump losses before retempering (mm).

S_{LR} = Slump losses after retempering (mm).

Using computer programs and incorporation of experimental data lead to formulation general equations, predicting previous dependent variables (Y) in term of the dependent variables (X) as following:

$$\gamma_D = K_0 + K_1 \times T + K_2 \times \frac{W}{C} + K_3 \times \frac{C + w}{S + G} + K_4 \times A + K_5 \times H + K_6 \times \gamma \quad (7)$$

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Where:

T = Temperature

A = Air content (%)

H = Humidity (%)

γ= Unit weight (kg/m³)

The coefficients value $(K_0, K_1, K_2, K_3, K_4, K_5 \ \& \ K_6)$ of the equation (1) and coefficient of correlation are determined for all the dependent variables and tabulated in Table 2.

Theoretical results obtained from the proposed equations found to be in a good agreement with the experimental data. Figures 1-6 show the relationship between theoretical and experimental results.

Hardened concrete

The dependent variables for hardened concrete are selected to represent the compressive strength$\left(f_c^{'}\right)$, flexural strength(f_r) split tensile strength (f_{sp}), static modulus of elasticity (E_{st}) and dynamic modulus of elasticity (E_{dy}), the following dependent variables are selected to represent hardened concrete properties:

$f_c^{'} = f_c^{'}$ at age (7 days) for initial stage (*MPa*).

$f_{c28}^{'} = f_c^{'}$ at age (28 days) for initial stage (*MPa*).

$f_{c7R1}^{'} = f_c^{'}$ at age (7 days) for first retempering stage (*MPa*).

$f_{c28R1}^{'} = f_c^{'}$ at age (28 days) for first retempering stage (*MPa*).

$f_{c7R2}^{'} = f_c^{'}$ at age (7 days) for second retempering stage (*MPa*).

Concrete Mix	Temperature (°C)	Water cement ratio (W/C)	(C+W)/(S+G)	Air content (A) %	Humidity (H) %	Unit weight (kg/m³)	Water Dosage		Final Slump (mm)	Dry U. Wt. (kg/m³)			Pulse Velocity (m/sec)			Losses in Slump (mm)	
							7 Day	28 Day		INIT.	1R.	2 R.	INIT.	1R.	2R.	Before R.	After R.
GI	30	0.4	0.43	2	22	2,388	0.45	0.79	76	2394	2405	2371	0.4776	0.4687	0.4632	10	37
G2	40	0.4	0.43	2	21	2,365	1.36	0.88	104	2369	2366	2376	0.4585	0.4498	0.4502	64	68
G3	50	0.4	0.43	1.8	28	2,348	1.95	2.26	101	2360	2351	2347	0.4561	0.4493	0.4491	68	63
G4	60	0.4	0.43	1.9	27	2,324	2.54	3.55	101	2347	2308	2265	0.4529	0.4478	0.4279	63	114
G5	65	0.4	0.43	1.9	30	2,263	2.68	1.8	114	2290	2251	2216	0.4383	0.4333	0.4267	90	114
G6	30	0.5	0.347	1.8	30	2.388	0.9	0.84	88	2423	2429	2430	0.4595	0.4335	0.4458	19	19
G7	40	0.5	0.347	1.8	30	2,408	0.99	0.76	71	2435	2422	2413	0.4766	0.4675	0.4646	29	25
G8	50	0.5	0.347	1.8	29	2,376	130	1.08	95	2426	2404	2368	0.4648	0.4638	0.4597	67	67
G9	60	0.5	0.347	1.8	30	2,386	1.02	1.26	88	2399	2381	2379	0.4657	0.4625	0.4604	35	50
G10	65	0.5	0.347	1.7	30	2,403	1.1	1.()6	88	2404	2415	2389	0.4677	0.4598	0.4569	69	75
G11	30	0.6	0.297	1..2	30	2,383	0	0.5	127	2411	2381	2405	0.4714	0.4622	0.4591	26	32
G12	40	0.6	0.297	1.2	30	2,409	0.82	0.7	88	2392	2392	2388	0.464	0.4617	0.4595	26	38
G13	50	0.6	0.297	1.3	30	2,393	1.06	1.23	114	2417	2386	2359	0.4636	0.4604	0.4548	70	57
G14	60	0.6	0.297	1.3	30	2,406	1.23	0.98	95	2403	2383	2398	0.4654	0.4596	0.4565	32	42
G15	65	0.6	0.297	1.2	30	2,402	1.27	0.94	95	2408	2390	2391	0.4656	0.459	0.4564	61	51
GIA	30	0.4	0.43	2	46	2,358	0.86	0.3	76	2392	2383	2377	0.4572	0.4505	0.4405	32	13
GSA	30	0.5	0.347	1.8	50	2,290	0.37	0.36	82	2414	2376	2369	0.4858	0.481	0.4696	60	52

Table 1a: Experimental data-1.

Mix	$f_c^{'}$ ***MPa***		$f_c^{'}$ **1st *RET.***		$f_c^{'}$ **2nd *RET.***		f_r ***MPa***			E_{st} ***MPa***			E_{st} **× 10E4 *MPa***			E_{dy} **× 10E4 *MPa***		
	7 Days	28 Days	7 Days	28 Days	7 Days	28 Days	INIT.	1R	2R	INIT.	1R	2R	INIT.	1R	2R	INIT.	1R	2R
G1	35.72	51.64	34.82	45.99	33.59	43.72	5.10	5.20	3.93	4.75	5.06	4.00	3.478	3.174	3.084	4.019	3.785	3.821
G2	35.85	42.05	36.13	44.68	34.13	42.06	5.37	4.86	4.55	4.60	4.55	3.89	3.441	3.233	3.092	3.62	3.62	3.745
G3	35.16	43.37	35.65	43.75	33.72	41.72	5.20	4.88	H6	4.92	4.60	4.17	3.21	2.923	2.874	3.663	3.661	3.685
G4	33.58	41.44	34.01	38.96	31.09	38.27	5.06	4.58	3.72	4.33	4.29	3.70	3.021	2.974	2.57	3.521	3.243	3.139
G5	31.71	40.28	33.62	39.2	29.6	36.93	4.90	4.72	4.03	4.20	3.23	3.00	2.776	2.52	2.162	3.317	3.191	3.054
G6	33.48	36.96	30.75	37.79	29.31	37.65	5.03	4.65	4.65	3.72	3.73	3.41	3.237	3.387	3.378	3.795	3.607	3.786
G7	34.82	39.72	33.24	37.44	31.17	36.41	4.96	5.06	4.65	4.03	3.58	3.10	3.445	3.311	2.898	4.179	3.935	3.941
G8	31.58	36.64	28.9	34.97	27.1	34.2	4.79	4.79	4.31	3.72	3.51	3.31	3.321	3.273	3.326	4.056	3.805	3.957
G9	31.37	36.82	30.96	34.34	27.03	32.97	4.82	4.61	4.55	3.72	3.17	3.06	3.445	3.293	3.431	3.899	3.976	3.866
G10	31.03	38.34	30.68	37.44	29.37	35.44	5.03	4.55	4.43	3.65	2.99	3.17	3.376	3.129	3.084	-	-	-
G11	25.27	34.96	26.27	35.03	27.44	35.44	4.44	4.62	4.31	3.37	2.99	3.37	3.177	3.129	3.17	-	-	-
G12	27.1	34.41	26	33.03	24.34	30.27	4.41	4.40	3.96	3.34	2.82	2.41	3.143	3.116	2.831	-	-	-
G13	24.34	31.51	24.68	31.17	23.03	27.24	4.58	4.41	3.86	3.20	2.81	2.96	3.196	3.018	2.913	-	-	-
G14	24.62	30.34	23.65	29.58	22.68	29.44	4.31	3.68	3.65	3.03	2.75	3.03	3.143	3.116	2.831	-	-	-
G15	23.51	32.13	22.27	32.27	21.93	32.57	4.48	4.17	4.24	3.44	3.03	2.86	3.177	3.191	3.17	-	-	-
G1A	36.48	42.62	34.68	41.44	32.82	40.2	5.22	5.00	4.86	3.79	3.55	3.44	1.374	1.374	1.367	-	-	-
G6A	33.38	37.65	31.93	36.96	31.51	36.75	5.50	5.19	5.13	3.51	3.27	3.17	1.382	1.408	1.367			

Table 1b: Experimental data-2.

Variables	K_0	K_1	K_2	K_3	K_4	K_5	K_6	r
Wd_{R1}	6.657	0.0336	-1.0285	6.837	-0.637	-0.0014	-0.0033	0.897
Wd_{R2}	31.908	0.0267	-28.154	-20.8	-3.16	-0.028	-0.0019	0.794
S_f	372.006	0.0946	162.344	313.162	-39.654	-0.718	-0.1636	0.728
γ_D	1970.73	-0.8137	-320.94	-1056.5	69.008	0.394	0.3686	0.9413
γ_{DR1}	1914.57	-1.0874	-1217.4	-1903.2	10.497	0.25	0.75056	0.965
γ_{DR2}	1945.38	-1.6192	-1338.6	-2016.1	-29.369	0.4789	0.8114	0.9375
V	0.6284	-0.0004	-0.1666	-0.3715	0.0099	-0.0005	0.00003	0.765
V_{R1}	0.4415	-0.0002	0.0802	-0.0884	0.0229	-0.0004	-0.0000039	0.5495
V_{R2}	0.627	-0.0003	-0.2536	-0.4904	0.00344	-0.0006	0.000066	0.8072
S_L	1106.99	0.901	-360.57	-411.13	-29.937	-0.3015	-0.3016	0.809
S_{LR}	1018.2	1.229	-167.01	-72.965	-24.95	-1.7375	-0.3458	0.9391

Table 2: The coefficients value of the eq. (1) of fresh concrete properties.

$f'_{c28R2} = f'_c$ at age (28 days) for second retempering stage (MPa).

$f_r = f_r$ for initial stage (MPa).

$f_{rR1} = f_r$ for first retempering stage (MPa).

$f_{rR2} = f_r$ for second retempering stage (MPa).

$f_{sp} = f_{sp}$ for initial stage (MPa).

$f_{spR1} = f_{sp}$ for first retempering stage (MPa).

$f_{spR2} = f_{sp}$ for second retempering stage (MPa).

$E_{st} = E_{st}$ for initial stage (MPa).

$E_{stR2} = E_{st}$ for first retempering stage (MPa).

$E_{stR2} = E_{st}$ for second retempering stage (MPa).

$E_{dy} = E_{dy}$ for initial stage (MPa).

$E_{dyR1} = E_{dy}$ for first retempering stage (MPa).

$E_{dyR2} = E_{dy}$ for second retempering stage (MPa).

$f'_{cL7R1} =$ Losses in f'_c at age (7 days) after first retempering (MPa).

$f'_{cL28R1} =$ Losses in f'_c at age (28 days) after first retempering (MPa).

$f'_{cL7R2} =$ Losses in f'_c at age (7 days) after second retempering (MPa).

$f'_{cL28R2} =$ Losses in f'_c at age (28 days) after second retempering (MPa).

$f_{rLR1} =$ Losses in f_r after first retempering (MPa).

$f_{rLR2} =$ Losses in f_r second first retempering (MPa).

$f_{spLR1} =$ Losses in f_{sp} after first retempering (MPa).

$f_{spLR2} =$ Losses in f_{sp} after second retempering (MPa).

$E_{stLR1} =$ Losses in E_{st} after first retempering (MPa).

$E_{stLR2} =$ Losses in E_{st} after second retempering (MPa).

The following equations are obtained:

$$f'_c = K_0 + K_1 * T + K_2 * \frac{W}{C} + K_3 * \frac{C+w}{S+G} + K_4 * A + K_5 * H + K_6 * \gamma \quad f'_c \tag{8}$$

where:

f'_c = Concrete compression strength *(MPa)*

T = Temperature

A = Air content (%)

H = Humidity (%)

γ= Unit weight (kg/m³)

Value of the coefficients $(K_0, K_1, K_2, K_3, K_4, K_5 \ \& \ K_6)$ for other variables and coefficient of correlation for all dependent variable (Y) are determined and tabulated in Table 3.

Theoretical results obtained from proposed equations found to be in good agreement with the experimental data. Figures 7-22 show the relationship between theoretical and experimental results.

Discussion

The experimental data given in literature [3] are used to predict empirical equation to estimate the concrete properties (fresh and hardened) depending on the mix properties and retempering of the concrete mix in hot weather. Value of the equation coeff. $(K_0, K_1, K_2, K_3, K_4, K_5 \ \& \ K_6)$ correlation coeff. (r) are determined for all independent variable. Value of (r) indicate that the estimated results are close enough to the experimental data for all independent variables as shown in Figures 1-6 for fresh concrete properties and Figures 7-22 for hardened concrete properties.

Variables	K_0	K_1	K_2	K_3	K_4	K_5	K_6	r
f'_{c7}	153.814	-0.085	-174.84	-175.51	-1.84	0.0179	0.0142	0.988
f'_{c28}	83.468	-0.109	-134.79	-64.676	-9.0366	-0.1504	0.0293	0.944
f'_{c7R1}	177.95	-0.0655	-172.93	-151.19	-6.207	-0.0414	0.0031	0.977
f'_{c28R1}	144.69	-0.121	-173.8	-105.99	-14.2	-0.015	0.0214	0.9809
f'_{c7R2}	218.463	-0.12	-209.7	-191.4	-11.641	-0.062	0.0043	0.971
f'_{c28R2}	207.63	-0.133	-221.82	-172.55	-16.642	-0.115	0.016	0.9545
f_r	20.648	-0.007	-13.06	-14.76	-0.085	-0.0034	-0.0014	0.911
f_{rR1}	28.09	-0.0157	-20.632	-23.149	-0.792	-0.0042	-0.0011	0.903
f_{rR2}	42.766	-0.0137	-35.291	-44.38	-1.4	0.023	-0.0011	0.8228
f_{spR1}	21.3556	-0.0049	-25.77	-17.761	-2.201	-0.0348	0.0028	0.978
f_{spR1}	-0.038	-0.0142	-10.08	1.184	-0.9353	-0.053	0.005	0.961
f_{spR2}	7.413	-0.0089	-11.509	-5.053	-1.0867	-0.0023	0.00266	0.8468
E_{st}	-2.377	0.0128	-16.86	-16.325	-1.3657	-0.0744	0.0099	0.913
E_{stR1}	-0.6543	0.0098	-16.361	-17.64	-1.2507	-0.6756	0.0091	0.8944
E_{stR2}	3.61	0.0074	-22.14	-25.18	-1.4604	-0.0614	0.01	0.885
E_{dy}	-16.907	0.0025	-	0.3081	1.227	0.0388	0.0724	0.914
E_{dyR1}	-12.873	0.0076	-	0.0664	-0.1458	-0.0032	0.007	0.9188
E_{dyR2}	7.3513	-0.002	-	-3.834	-2.6673	-0.0877	0.0022	0.95
f'_{cL7R1}	-24.135	-0.0194	-1.9116	-24.323	4.3677	0.0593	0.01111	0.7868
f'_{cL28R1}	-61.111	0.0121	38.748	40.9474	5.1608	-0.0001	0.00799	0.316
f'_{cL28R2}	-64.65	0.0347	34.858	15.886	9.8014	0.08	0.00994	0.777
f'_{cL28R2}	-124.16	0.024	87.029	107.88	7.6053	-0.0353	0.01336	0.4185
f_{rLR1}	-7.442	0.0089	7.573	8.39	0.7071	0.0082	-0.0003	0.505
f_{rLR2}	-23.337	0.0048	23.2311	33.6734	0.8203	-0.0246	-0.0003	0.7445
f_{spLR1}	21.4766	0.0093	-15.888	-19.224	-1.2656	0.0184	-0.0022	0.782
f_{spLR2}	13.9426	0.004	-14.261	-12.709	-1.1145	-0.0117	0.00012	0.6118
E_{stLR1}	-1.7227	0.003	-0.4992	1.3136	-0.115	-0.0096	0.00078	0.7077
E_{stLR2}	-5.987	0.0053	5.28	8.855	0.0947	-0.013	0.00016	0.656

Table 3: The coefficients value of the eq. (1) of hardened concrete properties.

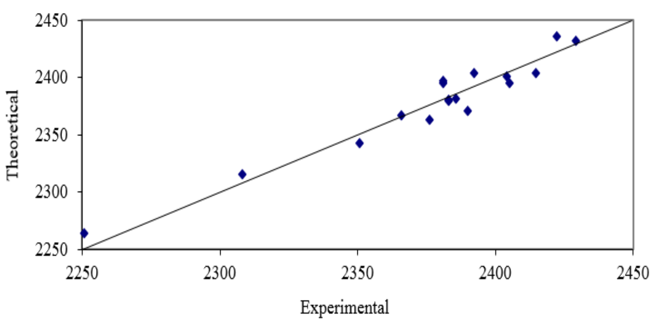

Figure 1: Relation of theoretical and experimental results of dry unit weight (γ_D) (Kg/m³).

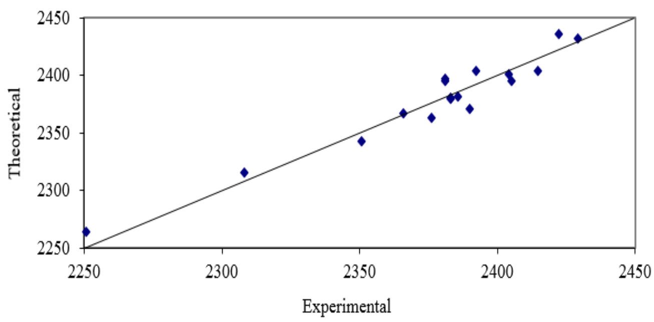

Figure 2: Relation of theoretical and experimental results of dry unit weight after 1st retempering (γ_{DR1}) (Kg/m³).

Citation: Rashid MHF, Agha AZS (2018) Prediction of Some Properties of Retempered Concrete in Hot Weather. J Civil Environ Eng 8: 324. doi: 10.4172/2165-784X.1000324

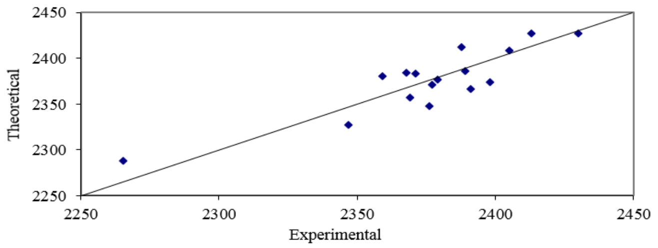

Figure 3: Relation of theoretical and experimental results of dry unit weight after 2nd retempering $\left(\gamma_{DR2}\right)$ (Kg/m³).

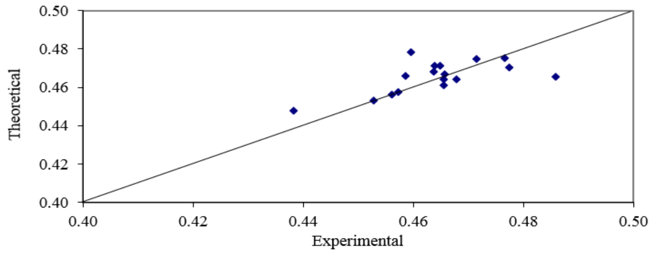

Figure 4: Relation of theoretical and experimental results of pulse velocity $\left(V\right)$ (m/sec).

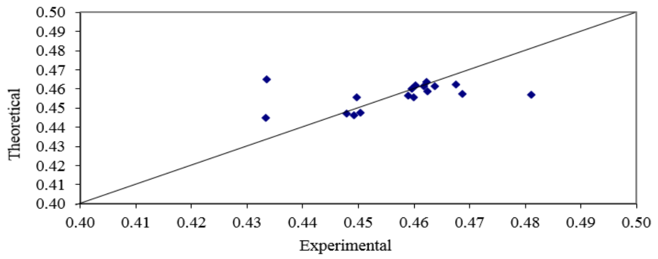

Figure 5: Relation of theoretical and experimental results of pulse velocity after 1st retempering $\left(V_{R1}\right)$ (m/sec).

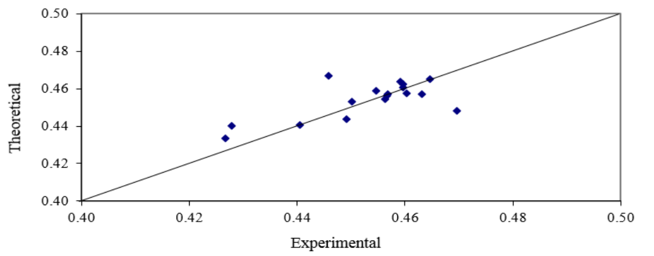

Figure 6: Relation of theoretical and experimental results of pulse velocity after 2nd retempering $\left(V_{R2}\right)$ (m/sec).

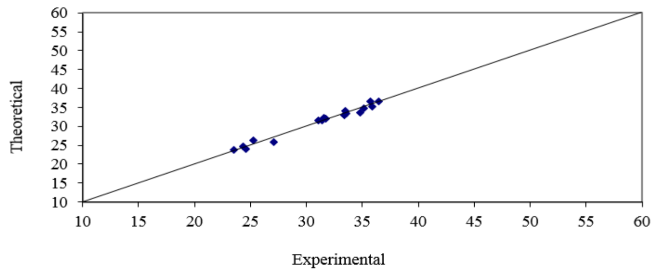

Figure 7: Relation of theoretical and experimental results of concrete compressive strength $\left(f_c^{'}\right)$ at age 7 days (*MPa*).

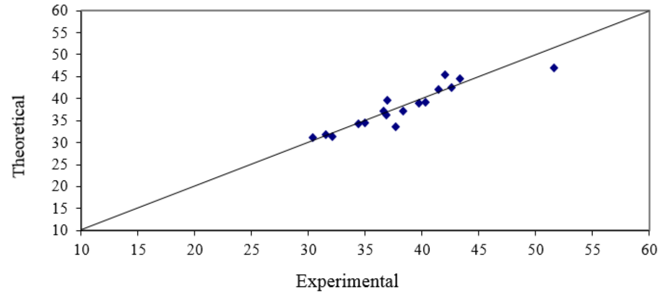

Figure 8: Relation of theoretical and experimental results of concrete compressive strength $\left(f_c^{'}\right)$ at age 28 days (*MPa*).

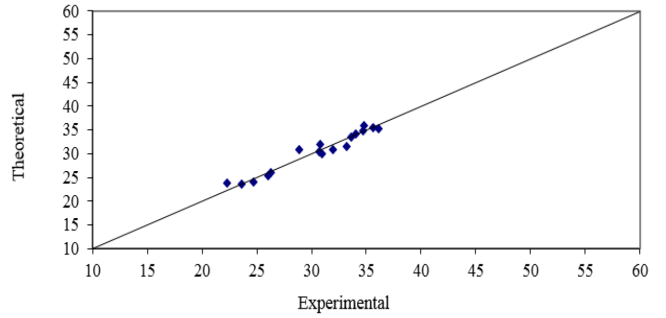

Figure 9: Relation of theoretical and experimental results of concrete compressive strength $\left(f_c^{'}\right)$ at age 7 days after 1st retempering (*MPa*).

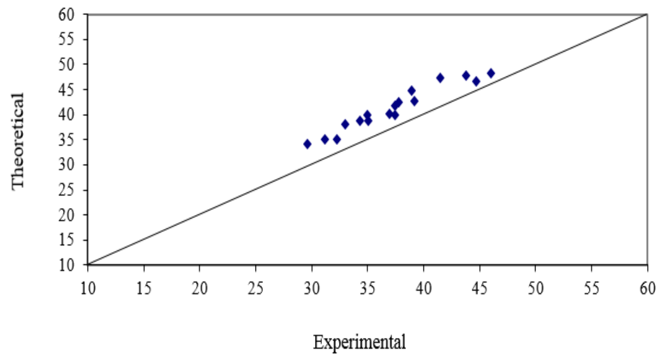

Figure 10: Relation of theoretical and experimental results of concrete compressive strength $\left(f_c^{'}\right)$ at age 28 days after 1st retempering (*MPa*).

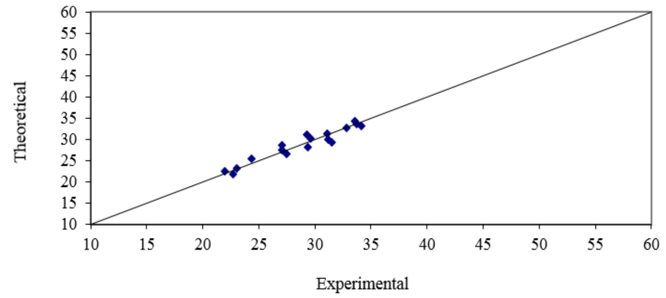

Figure 11: Relation of theoretical and experimental results of concrete compressive strength $\left(f_c^{'}\right)$ at age 7 days after 2nd retempering (*MPa*).

Citation: Rashid MHF, Agha AZS (2018) Prediction of Some Properties of Retempered Concrete in Hot Weather. J Civil Environ Eng 8: 324. doi: 10.4172/2165-784X.1000324

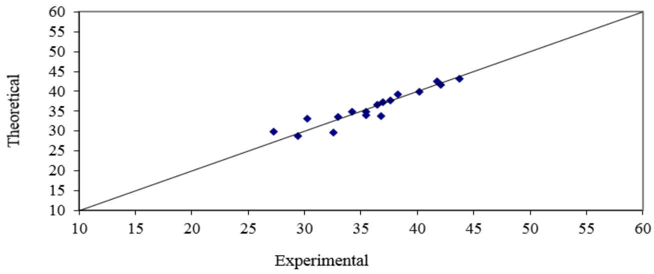

Figure 12: Relation of theoretical and experimental results of concrete compressive strength $(f_c^{'})$ at age 28 days after 2nd retempering (*MPa*).

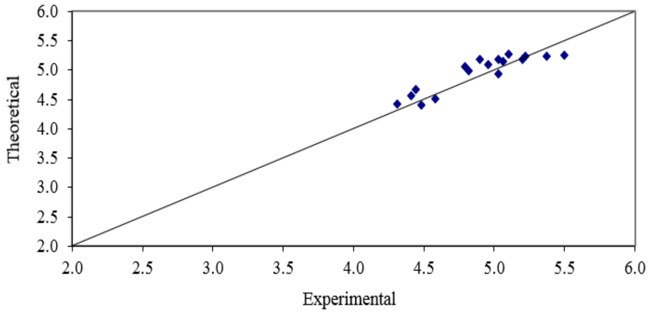

Figure 13: Relation of theoretical and experimental results of modulus of rupture f_r (*MPa*).

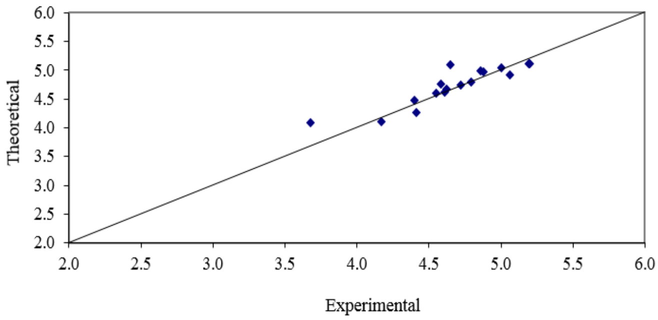

Figure 14: Relation of theoretical and experimental results of modulud of rupture (f_r) after 1st retempring (*MPa*).

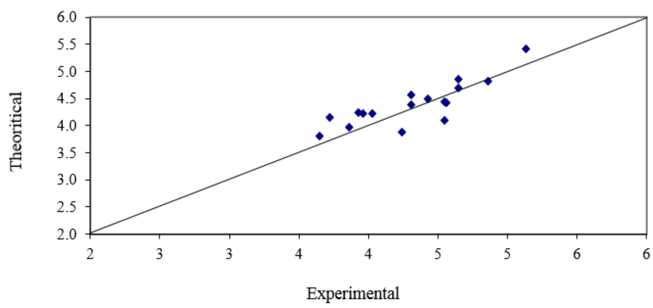

Figure 15: Relation of theoretical and experimental results of modulus of rupture (f_r) after 2nd retempring (*MPa*).

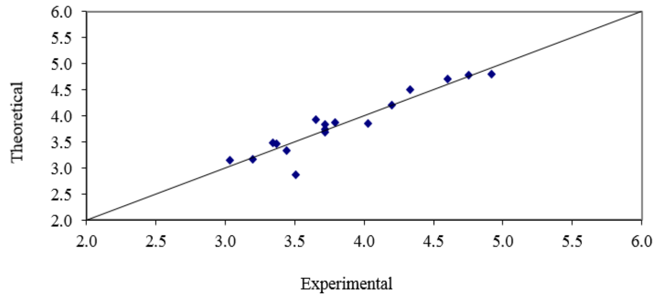

Figure 16: Relation of theoretical and experimental results of splitting tensile strength (f_{sp}) (*MPa*).

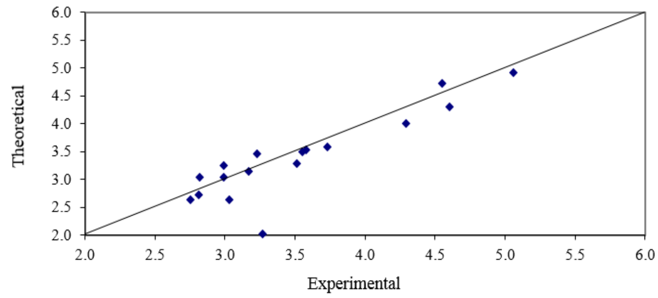

Figure 17: Relation of theoretical and experimental results of splitting tensile strength (f_{spR1}) after 1st retempering (*MPa*).

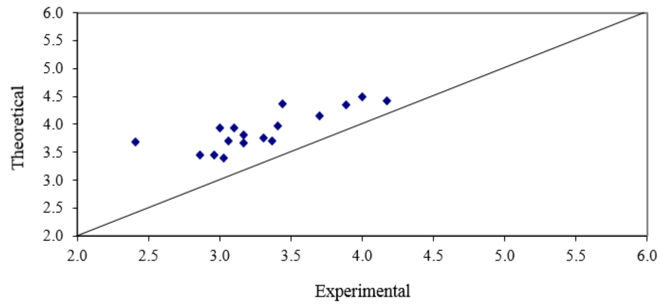

Figure 18: Relation of theoretical and experimental results of splitting tensile strength (f_{spR2}) after 2nd retempering (*MPa*).

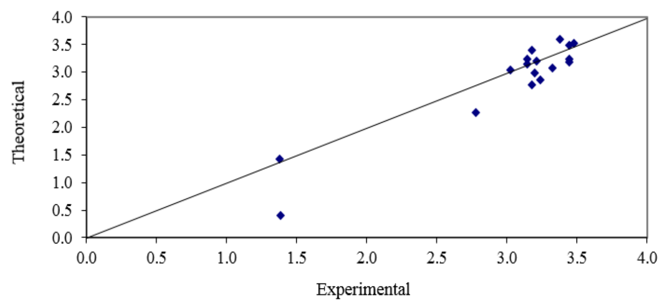

Figure 19: Relation of theoretical and experimental results of static modulus of elasticity $(E_{st})(^{*}10^{\wedge}4MPa)$.

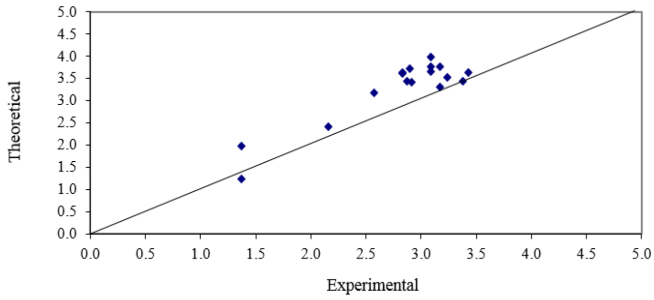

Figure 20: Relation of theoretical and experimental results of static modulus of elasticity $\left(E_{stR2}\right)$ after 2nd retempering $\left({}^{*}10^{\wedge}4MPa\right)$.

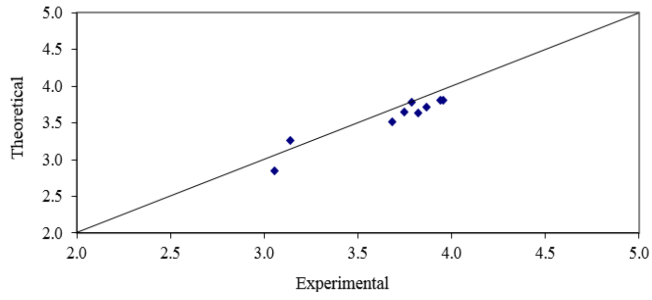

Figure 22: Relation of theoretical and experimental results of dynamic modulus of elasticity $\left(E_{dyR2}\right)$ after 2nd retempering $\left({}^{*}10^{\wedge}4MPa\right)$.

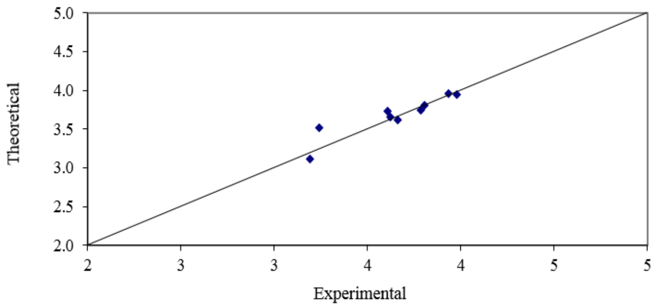

Figure 21: Relation of theoretical and experimental results of dynamic modulus of elasticity $\left(E_{dyR1}\right)$ after 1st retempering $\left({}^{*}10^{\wedge}4MPa\right)$.

Conclusion

It is possible to estimating some properties of the hardened concrete such as concrete strength (compressive, split tensile and flexural) also static and dynamic modulus of elasticity depending on the simple properties of the concrete mix with acceptable accuracy.

1. Also this paper presented empirical equations to estimating some properties of the fresh concrete such as (additional water for first & second retempering, slump and dry unit weight) depending on the simple properties of the concrete mix(water cement ratio, mix proportion, humidity, temperature, air content and unit weight).
2. This estimation is useful to predicting some properties of the fresh and hardened concrete after first and second retempering easily without needing measuring or casting and testing control specimens to get these properties.
3. Theoretical results obtained from these equations found to be in good agreement with the experimental data found in literature.

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