Effect of Using Well Water as Mixing Water in Concrete

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Abstract

Water quality has been a matter of concern in civil engineering projects. Most specifications require the use of potable water because its chemical composition is known and well regulated. In some situations where potable water is not ready available, many water types which are unacceptable for drinking may be satisfactorily used in concrete, such as the well water. In this study, Well water is being investigated the feasibility of using well water as a mixing water in concrete. Water samples were obtained from three different wells. The chemical properties of these samples were investigated in the laboratory. Eight mixes were prepared from two types of cement (ordinary and sulfate resisting Portland cements) and these samples of well water as well as distilled water in order to make a comparative study. The concrete specimens were cured and tested for compressive, splitting tensile and flexural strengths at (3, 7, 28) days. The results, when compared with the results of control mixes (made with distilled water), showed that same effect of well water on the concrete strengths approximately. Therefore, the well water with acceptable limits in its chemical analysis was suitable for use in production of concrete with acceptable strength.

Keywords: Concrete, Well Water, Mixing Water.

تأثير استخدام مياه الابار كماء للخلط في الخرسانة

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الخلاصة

تعتبر نوعية الماء من الامور المهمة التي لها علاقة بمشاريع الهندسة المدنية. إذ أن اغلب المواصفات تتطلب استخدام ماء الشرب بسبب تركيبه الكيميائي المعروف والمنتظم بشكل جيد. في بعض المواقع عندما لا يكون ماء الشرب متوفراً وجاهزاً للاستخدام فإن الكثير من انواع الماء غير الصالحة للشرب من الممكن أن يكون استخدامها ملائماً للخرسانة كما هو الحال في مياه الابار. في هذه الدراسة يتم التحقق من مدى ملائمة استخدام مياه الابار كماء للخلط في الخرسانة. تم أخذ عينات الماء من ثلاثة ابار مختلفة وقد أجري تحليلها كيميائياً في المختبر كما تم تحضير ثمان خلطات خرسانية من نوعين من السمنت (سمنت اعتيادي وسمنت بورتلاند مقاوم للكبريتات) مع عينات مياه الابار اضافة الى الماء المقطر. وقد تمت معالجة النماذج الخرسانية وفحص مقاومة انضغاطها و مقاومة الشد الانشطاري ومقاومة الانثناء عند الاعمار(3، 7، 28) يوماً. أظهرت النتائج بعد مقارنتها بنتائج الخلطة المرجعية (المحضرة من الماء المقطر). أظهرت تأثيراً مشابهاً لمياه الابار على مقاومات الخرسانة وبشكل تقريبي. لذلك فإن مياه الابار ذات الحدود المقبولة في تحليلها الكيميائي تعتبر مناسبة للاستخدام في انتاج خرسانة بمقاومة مقبولة.

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1. INTRODUCTION

Water is consumed in concrete technology as mixing water, for curing, and for washing aggregates and concrete equipment. Although the quantity of mixing water in a fresh concrete mix is of paramount importance in determining the properties and performance of hardened concrete, its quality also is a significant parameter [1]. Water is one of the most important elements in construction but engineers still ignore quality aspect of this element. Many times in spite of using best material i.e. cement, fine aggregate, coarse aggregate etc. in cement concrete, required results are not achieved. Most of engineers/constructors think that there is something wrong in cement, but they do not consider quality of water being used [2].

The quality of water is important because poor-quality water may adversely affect the time of setting, the strength development, or cause staining. Almost all natural waters, fresh waters, and waters treated for municipal use are satisfactory as mixing water for concrete if they have no pronounced odder or taste. Because of this, very little attention is usually given to the water used in concrete, a practice that is in contrast to the frequent checking of the admixture, cement and aggregate components of the concrete mixtures. In fact, most of the references appear to be outdated, but they still represent the bases for modern concrete technology with regard to water for mixing and curing [3]. A popular criterion as to the suitability of water for mixing concrete is the classical expression, "if water is fit to drink it is all right for making concrete". This does not appear to be the best basis for evaluation, since some waters containing small amounts of sugars or citrate flavoring would be suitable for drinking but not mixing concrete, and, conversely, water suitable for making concrete may not necessarily be fit for drinking [3].

Slightly acidic, alkaline, salty, brackish, colored, or foul-smelling water should not be rejected outright. This is important because of the water storage in many areas of the world [4]. Waterway Experiment Station to determine the effects of pH values of water on the strength of concrete and the staining properties of elements found in water. It was found that various contaminates can render distilled water unfit for mixing or curing concrete. It is also indicated that pH does not provide a basis for specifying quality of mixing water [5]. Impurities in water may interface with the setting of the cement and may adversely affect the strength of the concrete. The chemical constituents present in water may participate in the chemical reactions and thus affect the setting, hardening and strength development of concrete [6]. Excessive impurities in mixing water not only may affect setting time and concrete strength, but also may cause efflorescence, staining, corrosion of reinforcement, volume instability, and reduced durability. Therefore, certain optional limits may be set on chlorides, sulfates, alkalis, and solids in the mixing water or appropriate tests can be performed to determine the effect the impurity has on various properties. Some impurities may have little effect on strength and setting time, yet they can adversely affect durability and other properties [7]. Some bad effects of water containing impurities are following [2]:

- Presence of salt in water such as calcium chloride, iron salts, inorganic salts and sodium etc. are so dangerous that they reduce initial strength of concrete and in some cases no strength can be achieved. There is rusting problem in steel provided in the reinforced concrete.
- Presence of acid, alkali, industrial waste, sanitary sewage and water with sugar also reduce the strength of concrete.

- ❖ Presence of silt and suspended particle in water has adverse effect on strength of concrete.
- ❖ Presence of oil such as linseed oil, vegetable oil or mineral oil in water above (2%) reduces the strength of concrete up to (25%).
- ❖ Presence of algae/vegetable growth in water used for mixing in concrete, reduce the strength of concrete considerably and also reduce the bond between the cement paste and aggregate.

2. WELL WATER

A lack of potable water, an integral of constituent of concrete, has resulted in the search for possible alternatives. While almost any natural water that is drinkable and has no pronounced taste or odour may be used as mixing water for concrete, the rising cost of such waters has prompted research such as this. However, the substitution of potable water with another source has many associated problems and risks that must be eliminated in order to ensure the quality and performance of concrete remains unchanged [8]. The literature search indicated that various sources of non-fresh water including sea and alkali waters, mine and mineral waters, water containing sewage and industrial wastes, waste water produced from ready mix concrete plants, and solutions of common salt were previously tested for use in concrete mixtures. It is difficult to draw a common conclusion regarding the use of these waters in concrete mixtures since impurities that exist in each water type are different [9].

Unless approved by tests, water from the following sources should not be used [10]:

- ❖ Water containing inorganic salts such as manganese, tin, zinc, copper, or lead.
- ❖ Industrial waste waters from tanneries, paint, and paper factories, coke plants, chemical and galvanized plants, etc.
- ❖ Waters carrying sanitary sewage or organic silt.
- ❖ Waters containing small amounts of sugar, oil, or algae.

There are existing and new sources of water which may be suitable for direct replacement of potable water for concrete making or for dilution and processing of the concrete production operations water. They include reclaimed water, ground water and treated water from sewer mining or water mining [11]. Contractors in Iraq and especially in Mosul were sometimes faced with the problem of finding water of acceptable quality for their construction works outside the center of the city. Therefore, it was essentially to investigate the feasibility of using the well water or ground water in the construction. This water should be checked from time to time to make sure that it was not vulnerable to contamination. So, it will be a suitable source of concrete mixing water. It has a tendency to be saline or may contain appreciable amounts of dissolved carbon dioxide [10].

3. EXPERIMENTAL PROGRAM

This part deals with the various materials used in the present investigation, their choice, grading and relevant properties. It also discusses the tests performed and the selected specifications for the experimental part of the research.

3.1. Materials

The materials used throughout this research included cement, water (distilled water and three types of well waters, fine aggregate, and coarse aggregate, with no additives used.

3.1.1 Cement

The manufactured Iraqi cements that used during this study are included: an ordinary Portland cement known as "Karasta" brand from Karasta cement factory in Iraq as well as sulphate resisting Portland cement known as "Al-jisir" brand from Al-jisir cement factory in Iraq too. The two types of cement used are complied with Iraqi specifications (IQS, No.5, 1984). The physical properties for the two types of cement are given in tables (1) and (2) respectively, while the chemical properties are given in tables (3) and (4) respectively.

Table (1): Physical Properties of the Ordinary Cement Used "Karasta"

Property	Test Result	Standard (IQS, No.5, 1984)
Fineness (Residue on sieve No.170)	4%	Blaine = 230 m^2/kg (min)
Initial setting time (min.)	150	45 (min)
Final setting time (hr)	240	10 (max)
Specific gravity	3.14	
Compressive strength (MPa): at 3days at 7days	 16.4 25.9	 15.0 (min) 23.0 (min)

Table (2): Physical Properties of the Sulfate Resisting Cement Used "Al-jisir"

Property	Test Result	Standard (IQS, No.5, 1984)
Fineness (Residue on sieve No.170)	2%	Blaine = 250 m^2/kg (min)
Initial setting time (min.)	150	45 (min)
Final setting time (hr)	240	10 (max)
Specific gravity	3.14	
Compressive strength (MPa): at 3days at 7days	 20.3 29.5	 15.0 (min) 23.0 (min)

Table (3): Chemical Properties of the Ordinary Cement Used "Karasta"

Chemical Composition	Value (%)	Standard (IQS, No.5, 1984) (%)	Chemical Composition	Value (%)	Standard (IQS, No.5, 1984) (%)
SiO_2	19	----	C_3A	5.48	----
AL_2O_3	4.67	----	C_4AF	12.42	----
Fe_2O_3	4.08	----	Solid Solution	16.76	----
CaO	62.61	----	L.S.F	1.00	0.66 – 1.02
MgO	4.43	5.0 (max)	Free Lime	0.56	----
SO_3	1.41	2.8 (max)	Loss on Ignition	1.47	4.0 (max)
C_3S	69.25	----	Insoluble Residue	0.85	1.5 (max)
C_2S	2.23	----			

Table (4): Chemical Properties of the Sulfate Resisting Cement Used "Al-jisir"

Chemical Composition	Value (%)	Standard (IQS, No.5, 1984) (%)	Chemical Composition	Value (%)	Standard (IQS, No.5, 1984) (%)
SiO_2	19.80	----	C_3A	2.31	----
AL_2O_3	4.23	----	C_4AF	16.01	----
Fe_2O_3	5.26	----	Solid Solution	17.84	----
CaO	61.92	----	L.S.F	0.95	0.66 – 1.02
MgO	3.94	5.0 (max)	Free Lime	0.78	----
SO_3	0.80	2.5 (max)	Loss on Ignition	2.06	4.0 (max)
C_3S	65.32	----	Insoluble Residue	0.85	1.5 (max)
C_2S	7.49				

3.1.2. Mixing Water

Distilled water was used for mixing, besides three samples of well water. The location of their wells were: well water (1) from (Al-Fadhilyi region), well water (2) from (Rujim Hadeed region) and well water (3) from (Sumyer region). So fig.(1) shows the site of each well relative to the center of Mosul, besides the chemical analysis of these samples is explained in table (5) and compared with the standard limits of ASTM (C94). These analysis were made in the laboratory of environmental engineering in Mosul university.

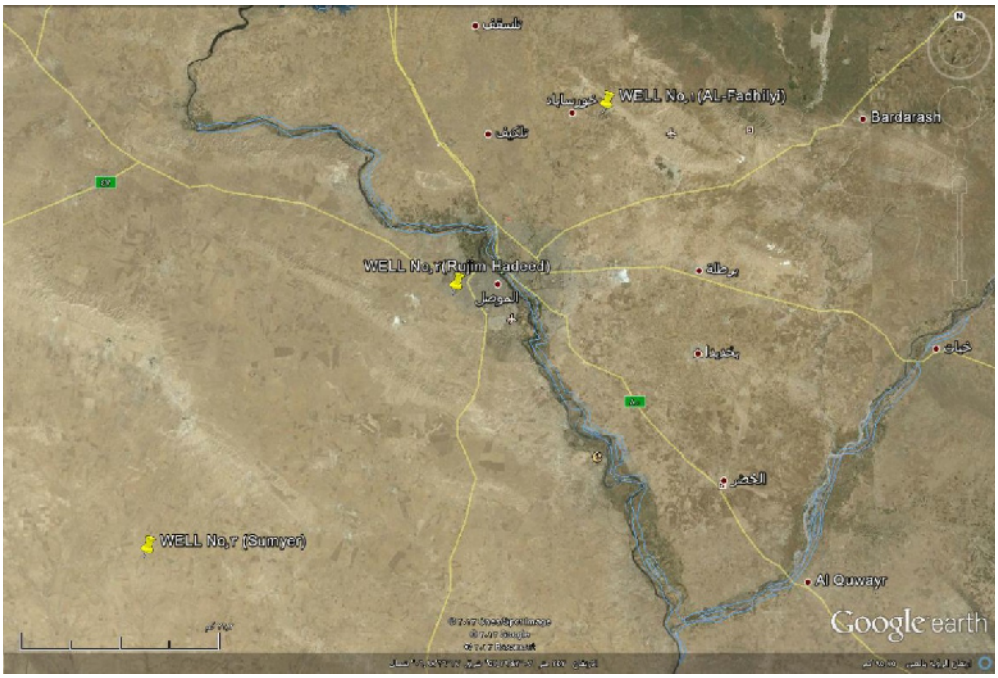

Fig.(1): The Site of the Used Wells Water

Table (5): Chemical Analysis for the Samples of Water

Chemical Compounds (mg/l)	ASTM (C 94) Limits (Maximum Concentration, ppm)	Well Water 1 (WW_1)	Well Water 2 (WW_2)	Well Water 3 (WW_3)
Chloride, as Cl	500	140	220	829
Sulfate, as SO_4	3000	195	1896	3407
Alkalies, as (Na_2O+0.658 K_2O)	600	164	120	128
Total Solids	50000	750	3000	6700
pH		8.15	7.3	7.7
Calcium, as Ca		88.2	408	449
Magnesium, as Mg		42.56	283.8	255

3.1.3. Fine Aggregate

Coarse sand in accordance with (BS 882 : 1992) was used in this investigation, available in the "Kanhash" area. The sieve analysis is listed in table (6).

Table (6): Sieve Analysis of Fine Aggregate

Sieve Size (mm)	% Passing on each Sieve				
	(O/A) Limits	% Passing of the Sample	Additional Limits		
			Coarse (C)	Medium (M)	Fine (F)
4.76	100	95	-	-	-
2.36	89-100	81	-	-	-
1.18	60-100	67	60-100	65-100	80-100
0.6	30-100	48	30-90	45-100	70-100
0.3	15-100	21	15-54	25-80	55-100
0.15	5-70	7	5-40	5-48	5-70

3.1.4. Coarse Aggregate

A locally coarse aggregate, available in laboratory of testing of construction materials was used in the research, round river gravel with (maximum aggregate size 20 mm). Their sieve analysis and grading were performed in accordance with (BS 882 : 1983), and given in table (7).

Table (7): Sieve Analysis of Coarse Aggregate

Sieve Size (mm)	Standard Limits	% Passing of the Sample
37.5	100	100
20	90-100	97
10	30-60	40
5	0-10	0

3.2. Mix Proportions and Specimens Preparation

The concrete mix proportion is chosen from some trial mixes. The mix proportion is (1:1.88:2.61/0.45) with a cement content (390) kg/m^3. The aggregate considered in (saturated surface dry) condition. Eight mixes were prepared maintaining two different types of cement (ordinary and sulphate resisting cement) with distilled water (DW) and three samples of well water (WW_1, WW_2, WW_3). The consistency (workability) of fresh mixes was evaluated by slump test according to (BS 1881: Part 102: 1983). Slump for each mix (100) mm, cube specimens (100) mm and cylinder specimens (100x200) mm were prepared in the laboratory. All the fresh mixes were cast into the moulds, and kept in their molds for about (24) Hrs in the laboratory and demolded, and subjected to moist cured for (3, 7, 28) days. The compressive strength of the concrete specimens was tested according to (BS1881:Part116: 1983), whereas the splitting tensile strength was assessed according to (ASTM C496) specification by the equation:

$$ft' = \frac{2P}{\pi DL} \qquad \text{……………………(1)}$$

where:
P: two equal compressive forces.
D: diameter of specimen (cylinder).
L: length of specimen (cylinder).

4. RESULTS AND DISCUSSIONS

An attempt to be more realistic, some writers of concrete specifications attempt to ensure that water used in making concrete is suitable by requiring that it be clean and free from deleterious materials. Some specifications require that if the water is not obtained from a source proven to be satisfactory, the strength of concrete or mortar made with the questionable water should be compared with similar concrete or mortar made with water known to be suitable [3]. The suitability of waters can be identified by carrying out performance tests such as compressive strength, as well as their adherence to guidelines which set limits for certain chemical properties, including sulfate, chlorides and total dissolved solids, in order to ensure the durability of concrete [8].

When water quality is questionable, service records of concrete made with the questionable water should be examined. If service records are not available or not conclusive, then the water quality should be clarified by comparing compressive strengths and time of setting of specimens made with the water in question and with distilled or 100 % potable water [3]. Table (5) shows the main criteria of the specification ASTM (C94) for the assessment the mixing water, compared to the results of the chemical analysis of the samples of water which used in the research, so the rest criteria that related to the compressive strength and setting time are shown in the table (8) [11]:

Table (8): Main Criteria of ASTM (C94) for Assessing the Mixing Water

Parameter	ASTM (C94)
Comparative Sample Strength	The mean 7-day compressive strength of the mortar or concrete samples prepared with the water must be at least (90%) of the mean strength of the control samples (prepared with distilled water or potable water).
Initial Setting Times	From 1:00 hr earlier to 1½ hrs later than control.

According to table (8), the mean 7-day compressive strength of the concrete specimens prepared with samples of well water (WW_1, WW_2, WW_3) were (27.9, 23.8 & 19.1) MPa respectively as well as the mean strength of control samples (made with distilled water

DW) was (30.3) MPa, so the type of well water (WW_1) was only suitable to use as a mixing water for concrete production according to the specification in Table (8).

The feasibility of using well water in concrete mixes was was investigated in this paper by studying the effect of this water on the concrete strengths (compressive, splitting tensile, flexural). The compressive strength results obtained on concrete samples prepared from the ordinary cement and sulfate resisting cement as well as (DW, WW_1, WW_2, WW_3) were depicted in fig.(2) and fig.(3) respectively.

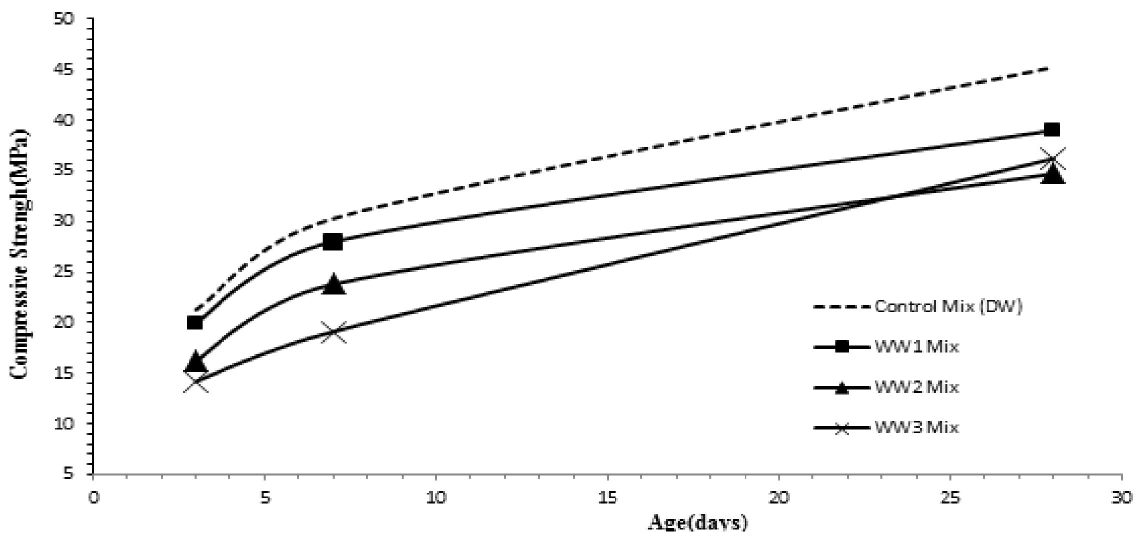

Fig.(2): Compressive Strength of Concrete Specimens (Made with Ordinary Portland Cement and Water Samples) with Curing Age

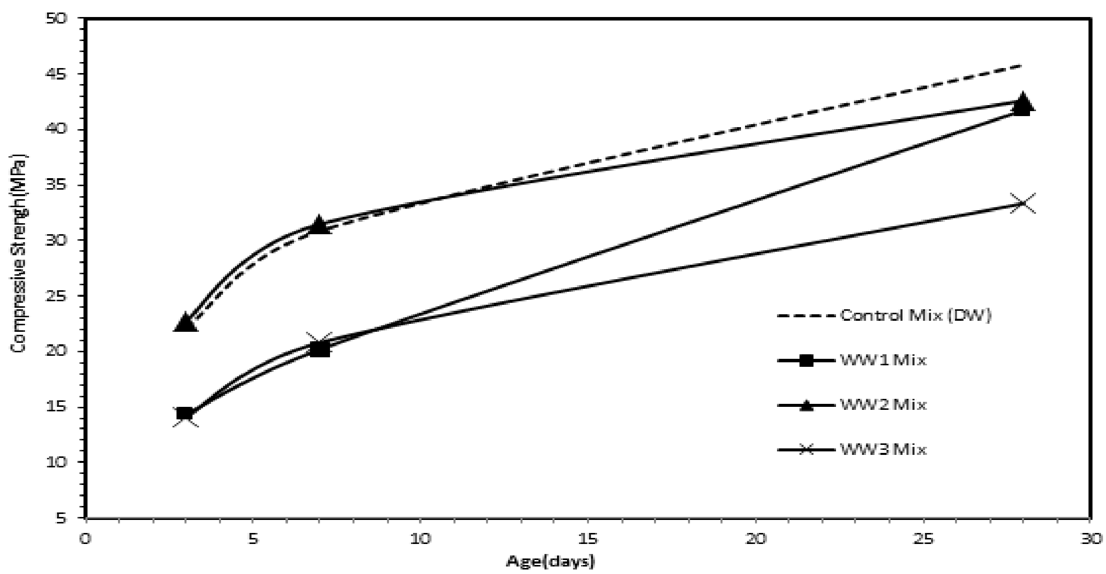

Fig.(3): Compressive Strength of Concrete Specimens (Made with Sulfate Resisting Portland Cement and Water Samples) with Curing Age

From fig.(2), it was noted that the compressive strength of the control mix (DW) was the highest, compared to the other mixes (WW_1, WW_2, WW_3) at all ages. While in fig.(3), it was observed that the compressive strength of the mix (WW_2) was higher than the control mix (DW) at (3, 7) days with a little increase (2.6, 2) % respectively, but at (28) days, the compressive strength of the mix (WW_2) decreased by (7) %, compared to the control mix (DW) which maintened the highest value.

From fig.(4), it was shown that splitting tensile strength of the mix (WW_1) has a lowest value at (3, 7) days, so the rate of reduction reached to (25.2, 38.1) % respectively, compared to the control mix (DW), but at (28) days, the (WW_1) mix maintened a largest splitting tensile strength which increased by (12.7) %. Besides, it was noted in the fig.(5) that the behavior of mix (WW_1) was the same as it in fig.(4), so the rates of reduction of the splitting tensile strength at (3, 7) days were (59.4, 53) % respectively as well as this strength rises at (28) days at a rate (31.7) % compared to the control mix (DW).

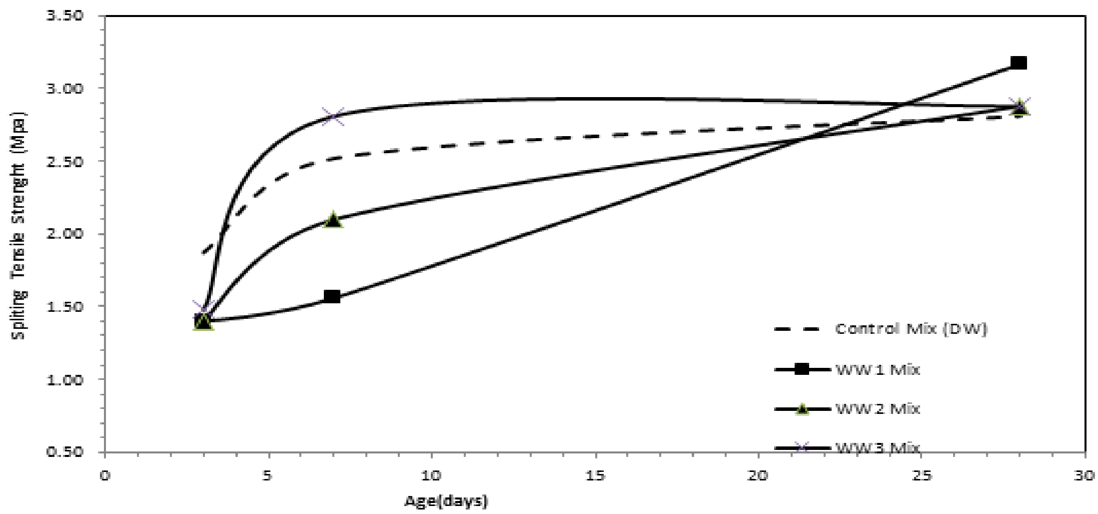

Fig.(4): Splitting Tensile Strength of Concrete Specimens (Made with Ordinary Portland Cement and Water Samples) with Curing Age

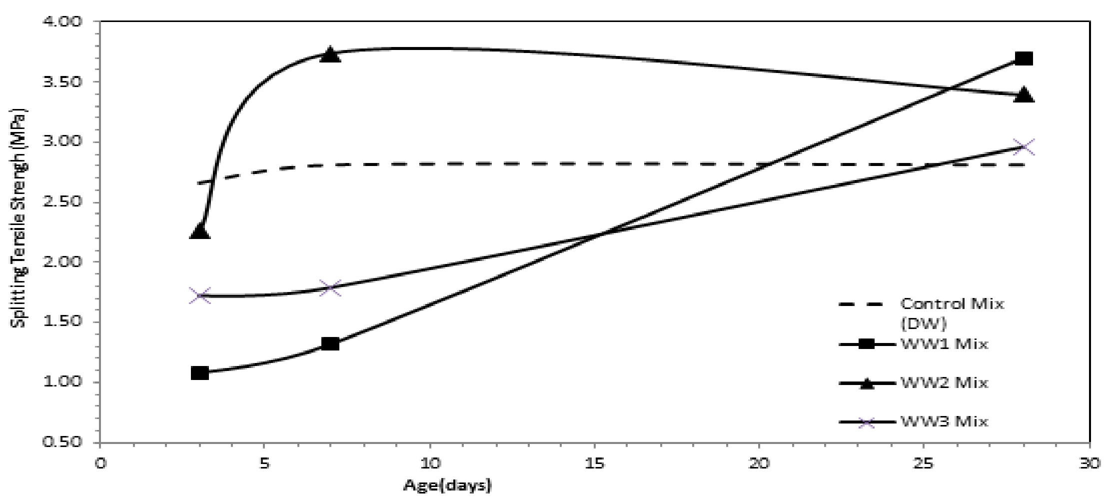

Fig.(5): Splitting Tensile Strength of Concrete Specimens (Made with Sulphate Resisting Portland Cement and Water Samples) with Curing Age

It was noticed from fig.(6) that the highest 3-day flexural strength was obtained in (WW_1) mix, So it was decreased by (4.7) % compared to (DW) mix which satisfied a highest value at (7) days, but at (28) days, the highest flexural strength was obtained from the (WW_3) mix, so the rate of increasing was reached to (11.9) % compared to the control mix (DW) mix.

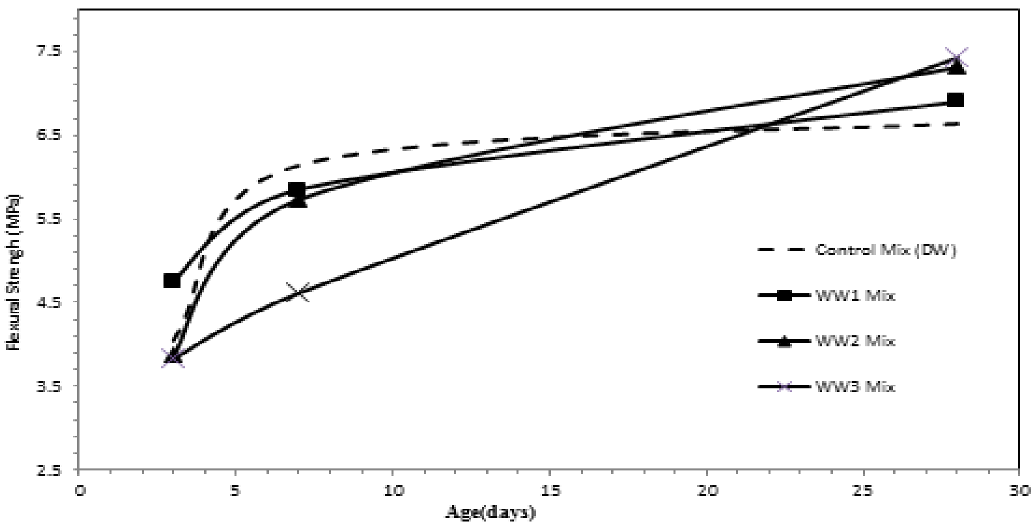

Fig.(6): Flexural Strength of Concrete Specimens (Made with Ordinary Portland Cement and Water Samples) with Curing Age

In the fig.(7), the (3) days, flexural strength was a largest in the (DW, WW_2) mixes respectively. So, the strength value reduced in the (WW_2) mix by (4.9) % at (7) days, compared to the control mix (DW). Finally, at (28) days the flexural strength increased by (17.2) % to be a largest value for the (WW_2) mix, compared to the control mix (DW).

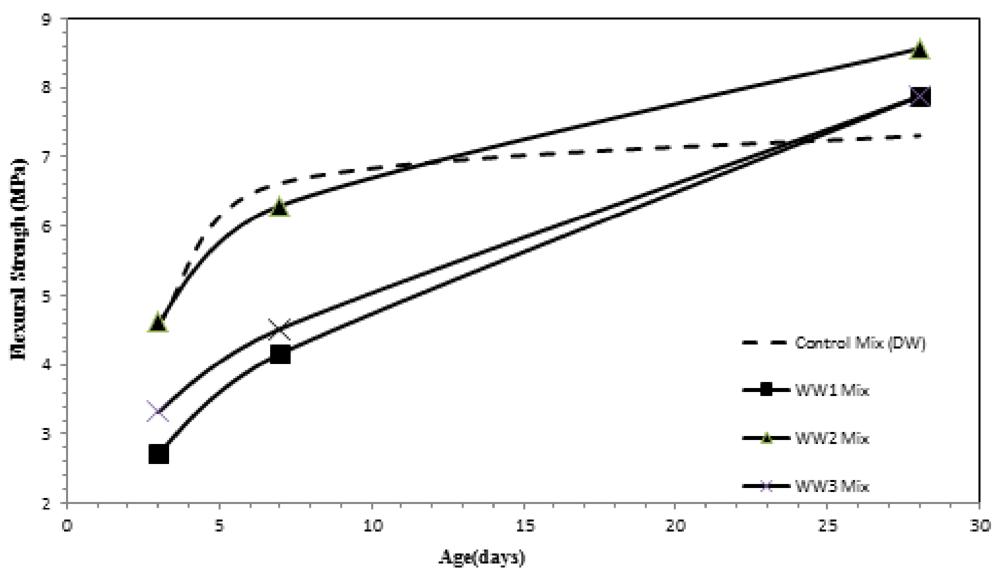

Fig.(7): Flexural Strength of Concrete Specimens (Made with Sulfate Resisting Portland Cement and Water Samples) with Curing Age

Based on the results, the well water was found to be permissible for mixing concrete (with the two kinds of cement) especially after making the typical analysis and compare it with the limits of specification because the water naturally contains a wide range of dissolved chemical including (chlorides, sulfates, alkalis…..etc) and when these compounds lie in the standard limits, it may be harmless or even beneficial when used in mixing in plain concrete. Besides, this is an evidence in the table (5) which appeared the similarity in the results of analyses of the distilled water and well water (WW_1) which was best type of the well waters used.

Thus, specifications usually set limits on chlorides, sulfates, alkalis, and solids in mixing water to ensure minimal adverse effects to the resultant concrete. Currently, unless tests can be performed to determine the effect the impurity has on various properties of fresh, hardening and hardened concrete, potable water must be used. Previous research coupling analytical techniques to determine impurities, with chemometric methodologies, to identify their relationships and influence was used by, Shrestha and Kazama. This research facilitated the characterization of impurities as well as an evaluation of water quality and offered conclusions as to its suitability for final use. These water quality indicators can be categories as [8]:

- ❖ Biological: bacteria, algae.
- ❖ Physical: temperature, turbidity and clarity, colour, salinity, suspended solids, dissolved solids.
- ❖ Chemical: pH, dissolved oxygen, biological oxygen demand, nutrients including nitrogen and phosphorus, organic and inorganic compounds including toxicants.
- ❖ Aesthetic: odours, taints, color, floating matter.

The water quality information gained by research and tests such as this can then be used to develop management programs and action plans to ensure that suitable water sources are adopted [8].

5. CONCLUSIONS

Based upon the experimental study, it was concluded as a possible option for the use of well water as a mixing water in concrete after meeting concrete mixing-water reqiurements by analysis the water chemically and compare it with the specification. Also, the used types of well water with two types of cement indicated a similar effect to the distilled water on the concrete strength. From the results, the control mix (made with ordinary cement) maintened a highest value of compressive strength at all ages. So, the mix (WW_2) (made with sulfate resisting cement) gain a compressive strength approximately to that in the control mix at ages (3, 7) days but at (28) days, it was decreased by (7) %. Concerning the splitting tensile strength, it was observed that the mix (WW_1) with two types of cement gained a lowest value at early ages, so it was rised at (28) days. For flexural strength, the mix (WW_1) (made with ordinary cement) maintened a hightest strength at (3) days, while at (7) days the control mix satisfied a hightest value, so at (28) days the flexural strength for the mix (WW_3) will be a largest. Besides, the 3-day flexural strength was a largest in the (DW, WW_2) mixes (made with sulfate resisting cement) respectively. So, this strength stayed as a hightest at (7) days. Compared to the control mix, the (WW_2) gained a largest flexural strength at (28) days.

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