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QUALITY OF MIXING WATER IN CEMENT CONCRETE "A REVIEW"

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Abstract

Potable water is a precious and scarce commodity in developing and developed countries. Due to increase in population and rapid industrialization, huge volume of limited potable water is being consumed at a faster rate as a result huge volume of wastewater is being generated. Partially treated and treated wastewater is to be reused where ever it is possible for sustainable development. Construction industry is the one in which the rate of consumption of concrete is almost as same as that of consumption of water. Hence, this paper emphasizes a detailed study to use non-potable water in concrete referring to the existing broad standards available in various codes of mixing water for concrete.

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Keywords: Standards of mixing water in concrete, Solids; Alkalinity, Acidity, Chlorides, Sulphates.

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1. Introduction

Water is the basis of life and it sustains all biological life, eco-systems and human activities. Most of the world's water is found in seas and oceans which is not potable. Only about 2% of water is fresh out of which 97% is tied up in the polar caps in the form of permanent snow and in deep depths below the ground. The remainder (i.e. 3%) is renewable through the cycle of precipitation and evaporation form. Even this water will not be available as and when we require [1]. It is actually scarce on the earth and it has no substitute. Despite the quantity of fresh water available is constant on this earth, due to the increase in population, urbanization and rapid industrialization the volume of potable water consumption is increasing ever year, thereby the volume of wastewater generation increases proportionately.

Concrete technology is one of the largest industries, which is consuming huge quantity of potable water. The rate of consumption of concrete is as same as that of the rate of consumption of water [2]. Water is one of the most vital ingredients of cement concrete and is mandatory for curing, washing of aggregates and concrete equipment. Water has both beneficial as well as detrimental effects on concrete [3]. Water using for mixing and curing of concrete or mortar should be free from deleterious chemical substances, which are likely to exert appreciable influence on properties of concrete like setting time, workability, strength development and durability. In practice, very often, a greater control on the properties of cement and aggregate is exercised, but the control on the quality of water is often neglected. A popular yardstick on the suitability of water for cement mortar or concrete is that, if the water is fit for drinking, it is fit for making cement mortar or concrete also. However, this doesn't appear to be true for all conditions. Water containing a small quantity of sugar may be suitable for drinking but not fit for using in cement mortar or concrete and conversely, water suitable for making concrete or mortar may not necessarily be fit for drinking especially if the constituents of salts present in water at more than the maximum permissible limits. Again, the standards of water may slightly vary for producing plain cement concrete and reinforced cement concrete. Hence, depending on the application and environment, close scrutiny and a guideline document on the use of non–potable water in concrete is needed.

2. Previous Research on Quality of Water in Concrete

Water quality has been a matter of concern in Civil Engineering construction [3, 4]. Water used for concrete shall be reasonably clean and free of oil, acid, alkali, organic matter or other deleterious substances [5-9]. Water use for mixing and curing concrete would be satisfactory if it is potable and fit for human consumption [10-14]. Potable water is suitable as mixing water for cement concrete, plain cement concrete for road construction and other applications, since its chemical composition is known and well regulated[15,16]. Drinking water is largely used as mixing water for concrete [8, 9, 17-19]. Water is considered suitable if it neither changes the setting time by 30 minutes nor reduces the strength by greater than 20% when compared with the setting time and strength of specimens prepared by using potable water [11, 20]. The 7 and 28 days strengths of specimens prepared with unknown water should be at least 90% of those obtained with specimens prepared with potable water [21]. The compressive strength of concrete cubes made of unknown water is not less than 90% of cubes made with tap water [20]. The reduction in compressive strength up to 20% can be acceptable, but the mixture proportions should be adjusted as appropriate [20]. In some situations where potable water is not readily available, many types of water which are unacceptable for drinking like sea water, which contains 70 fold the maximum tolerable total dissolved solids (500 mg/L) in drinking water may be satisfactorily used [16].

Concrete mixing water is generally required to comply with British Standards [20], standards of the American Society for Testing and Materials [8] or with the Indian Standards [21]. The standards specified for various aspects of water do not represent the true picture of their impact on setting and strength development of concrete. In addition to that, a brief review of literature suggests that very little work has been done relating to the effect of impurities that may exist in water. Broad tolerant limitations can be found in the literature. No ACI recommendation or ASTM standard concerning the quality of mixing water for concrete [16] are available. Mixing water limitations in concrete are stringent ones [22, 23]. Standards of mixing water in concrete are very general [24-26]. Nevertheless, it is believed that presently available information is inadequate to set up rigid specifications for maximum amounts of impurities that may present in mixing water [23]. However, various sources of non-fresh waters were previously tested for use in concrete mixtures and cement. Various sources of non-fresh waters such as sea, alkali waters, mine and mineral waters, waters containing sewage and industrial wastes and oily and brackish waters from oil wells that are tested for use in concrete mixtures [16, 17, 27-32]. Effect of unknown water samples on workability, setting time and compressive strength of mortar and concrete is studied [26, 33, 34]. Pond or lake water having low contents of silt, organic matter, or other impurities has little or no adverse effect on concrete properties is suitable for mixing water in concrete [35]. Water from streams or rivers that is not subjected to pollution by domestic sewage, and do not have a brackish or salty taste, has been found to be suitable for concrete mixing [36]. Treated effluent is used to prepare cement slurry at a cement factory in Dubai [37]. Treated effluent is used as satisfactorily as concrete mixing, curing and washing aggregates and sea water can be used in plain concrete structures even permanently submerged in a marine environment [38, 39].

The use of reclaimed waste water for concrete mixing suggest that, such water can be used as mixing water in concrete without any harmful effects [40]. The unknown water tensile strength of concrete is about 10-15% and occasionally 20% of the compressive strength of potable water [41]. Domestic sewage has no significant effect on setting times as per [20, 42, 43] even before biological treatment and confirmed the feasibility of using biologically treated wastewater in concrete technology [16]. Total solids of 50,000 ppm can be tolerated when wash water is used to make concrete [44]. 90% of the compressive strength is retained in the cement mortar and concrete specimens when the proportion of the treated effluent does not exceed 20% in the mixing water and the setting time for the cement mortar also lies within the limits prescribed by the [20,28].

The age of wash water has the great effect on strength with an increase of up to 20%, while workability and permeability are reduced and Sulphate resistance is also increased [45]. Magnetic field treated water in concrete has improved compressive strength as much as 10% higher than the tap water [46, 47]. In some situations where potable water is not readily available, many water types which are unacceptable for drinking may be satisfactorily used in concrete, road construction and other applications [15]. The magnetic field treated water can penetrate the core region of cement particles more easily; hence, hydration can be done more efficiently which in turn improves concrete strength [48]. The compressive strength of mortar samples mixed with magnetic field treated water is higher than those prepared with tap water. In addition to that it reduces the amount of cement used and does not require the addition of chemical admixture water [49-51].

Sludge water leads to the reduction of concrete capillary water absorption and porosity, and possibly improves the durability of concrete [52]. The effective use of the recycling sludge water in concrete production would be of great benefit both in disposal cost reduction and environmental conservation [53]. The use of waste wash water as mixing water in concrete, shows that the 28-day compressive strength of mixes are 96% of those of the control mix [52]. Recycled water in concrete has reduced 10% strength but improves water tightness compared with control mix [54]. Wash water can be used as mixing water for ready mixed concrete without affecting the compressive strength [55]. Tertiary treated wastewater is found to be suitable for mixing concrete with no adverse effects [56]. The compressive strength of mortar samples mixed with magnetic field treated water (MFTW) is higher than those prepared with tap water [51]. Non – fresh water (production water) generate acceptable 28 day strength for flowable fill mixes [57]. Recycled water has no effect on the setting time and strength of concrete [58]. The compressive strengths of concretes mixed with sludge water are in the range of 85-95% of normal concrete, which are comparable to ASTM C94 requirement on mixing water for concrete. Also, the modulus of elasticity of concretes is more than the suggested value when compared with ACI 318 standard [59].

Water contaminated with algae (650 cells/ml) is used as mixing water in cement [60]. Heavy metals (Pb, Zn, Cu, Ni) in mixing water are friendly with cement mortar up to 600 mg/L [61]. The compressive strength of concrete cubes made with untried water exhibits not to be less than 90% of cubes made with tap water [31]. Recycled water from ready-mix concrete plants can be suitable for use as mix water in concrete making [62]. The strength of concrete of the mixtures prepared using wastewater is comparable with the strength of the control mixture and also, the water absorption of concrete is not affected when wastewater is used [63]. Lead concentration in mixing water of cement is permitted up to 2000 mg/L [64]. The research literature on the use of wastewater in concrete reveals that

much work needs to be done on water use in concrete and there is a need to review the existing standards on water quality in light of the emergence of various types of cementitious materials and water reducing admixtures [3].
Standards of most of countries revealed that water containing less than 2000 mg/L of total dissolved solids (TDS) and 2000 mg/L of suspended solids (SS) generally is considered suitable, unless it is suspected of carrying certain uncommon but harmful impurities, even in small quantities [11, 25]. European literature and international experience with the difficulties of quality concrete production in the Middle East and other adverse environments provide concrete technologists with more specific recommendations [20, 42, 43]. BS 3148 specifies comparative setting time and strength tests besides recommending the following general limits of inorganic constituents: chlorides maximum in RCC 500 mg/L; total sulfates 2000mg/L, Total alkalinity 500mg/L, other dissolved solids maximum 2000 mg/L, and suspended solids maximum 2000 mg/L. For example, solids are divided into organic solids (biodegradable and non biodegradable) and inorganic solids. No code is a specified limit of a particular organic or inorganic constituent and a particular combination of them in mixing water of concrete. In general, the sulfates encountered in mixing water, soils and ground water are $CaSO_4$, $MgSO_4$, Na_2SO_4, $(NH_4)_2SO_4$ and $FeSO_4$. Literature is revealed that among sulfates, magnesium sulfate is most vulnerable to concrete but the limit of a particular sulfate and a combination of sulfates in concrete is not given by any code. Like this, carbonates, bicarbonates, hydroxide, hard water with calcium and magnesium, heavy metals, sodium, potassium, fluoride, nitrogen, phosphorous, chlorides, biological constituents etc., are not studied in detail. The above constituents in mixing and curing waters for concrete have to be studied extensively. Because, quality of water is varying from place to place and potable water is not available at all construction sites. In general, available water at construction site is used for mixing and curing of concrete.

Mixing water standards in concrete will vary from country to country code. The tolerable limits of various constituents of water used in concrete mixing in various country codes are presented in the Table.1. In near future, developed and developing countries have to be reused treated and partially treated wastewater in huge quantity in concrete works. Hence, in order to use Non-potable water as mixing water in concrete or cement, detailed study on existing permissible limits of constituents in mixing water of concrete in many codes is essential.

By maintaining the proper alkalinity of water, the pH will stay around the ideal levels.Table.1, pH is given in between 3 to 9 [18, 20, 21, 40, 65, 66, 67] but the ideal pH range for water is between 7.2 and 7.6. This means that the water is slightly basic.

There is totally confusion on solids; from Table: 1 total solids were given in wider range i.e, 4000 to 50000 [8, 24, 65]. The suspended solids are given as 2000 mg/L [11, 21, 42], and dissolved solids are given in between 2000 to 50000 mg/L [20, 21, 42, 68, 69]. The organic solids are given 200 mg/L [21]. The inorganic solids are given 3000 mg/L [21]. However, the total solids are classified as suspended solids and dissolved solids. The suspended solids consist of both organic and inorganic solids. And the dissolved solids consist of organic and inorganic solids. Therefore, the total organic solids are sum of organic solids in suspended form and organic solids in dissolved form. The total inorganic solids are the sum of inorganic solids in suspended and inorganic solids in dissolved. Hence, the total solids are equal to the sum of total organic solids and total inorganic solids or the sum of total suspended solids and total dissolved solids. Moreover, except pH in all parameters of mixing water standards, remaining all should be equal to total solids or sum of total organic solids and total inorganic solids. But it is not matched in any code.

There are no same limits in solids (Table .1) in various country codes and researches in particular [21], it has given that suspended solids, dissolved solids, organic solids and inorganic solids are 2000, 2000, 200, 3000mg/L respectively. From the above paragraph, the total solids are equal to the sum of suspended solids and dissolved solids or sum of organic solids and inorganic solids. Hence, in [21] the sum of total organic (200) and inorganic solids (3000) are 3200 mg/L, and the sum of suspended solids (2000) and dissolved solids (2000) are 4000 mg/L, it is clear that total solids are not same; the deference of 800 mg/L indicates that contrast information in the same code and also among various codes. Hence, the total organic and inorganic solids limit have to be estimated such that they should be equal to the total solids.

From table.1, Alkalinity is not same in various countries codes and researchers [10, 11, 20, 24, 66, 67]. Particularly the total alkalinity [11] has been given due to carbonate and bicarbonate as 1000, 400 mg/L respectively. However, alkalinity in water gets contributed due to carbonates, bicarbonates and hydroxides. Total alkalinity is sum of the carbonates, bicarbonates and hydroxide. Hence, the word total alkalinity not supposed to use in any code unless include alkalinity due to hydroxide. Also, no limit of alkalinity due to hydroxide is available.

No limit on acidity in mixing water of concrete is available. Acidity gets contributed in water due to carbon dioxide (CO_2) and minerals i.e, H_2SO_4, HCl, HNO_3 and H_2CO_3 etc. The total Acidity is sum of the carbon dioxide and minerals acidity. Limit for H_2SO_4 is given in [17] and HCl is given in [24]. No limit is available for Carbon dioxide acidity. Hence, carbon dioxide acidity and total acidity have to be evaluated separately for plain and Reinforced cement concretes.

From table.1, permissible limit of sulphates is not same in codes and accord to researchers [8, 21, 66, 67, 68, 70, 71, 72]. Generally, sulphates encountered in surface water, ground water and soils are $CaSO_4$, $MgSO_4$, Na_2SO_4, $(NH_4)_2SO_4$ and $FeSO_4$. No limit is available on a sulphate. Even though $MgSO_4$ is most vulnerable to concrete, no limit is available. Hence, individual sulphate limit and sulphates in a combination limit have to be evaluated.

From table.1, permissible limit of chlorides for plain concrete [21, 42, 66, 67, 72, 73] and reinforced concrete [8, 10, 20, 21, 72] is also not same in all codes. Generally, calcium chloride ($CaCl_2$), sodium chloride (NaCl) and magnesium chloride ($MgCl_2$) are present in water. $CaCl_2$ and NaCl are used as accelerating admixtures also. Hence, individual chloride limit and chlorides limit in a combination have to be evaluated in mixing water for plain and reinforced cement concrete.

Table 1: Tolerable Limits of Constituent in Mixing Water in Concrete

(All values in mg/L except pH)

Constituent	Tolerable Limits	References
pH	3 >5 6 6-8 7-9	[40,65] [66,67] [21] [18] [20]
Total solids	50000 5000-10000 4000	[8] [24] [65]
Suspended solids	2000	[42,11,21]
Dissolved solids	50000 2000 <6000	[68] [42,21,20] [69]
Organic solids	200	[21]
Inorganic solids	3000	[21]
Total Alkalinity(as CaCO3)	500 1000	[20] [10,11]
Sodium Carbonates and Bicarbonates	2000	[66,67,24]
Carbonate	1000	[11]
Bicarbonate	400	[11]
Na, K, Ca and Mg	2000	[20]
Sulphates	400 600 1000 2000 3000	[21] [70] [66,71,72] [66-68] [8]
Chlorides for plain concrete	360 500 2000 4500	[73] [66,67,42] [21] [72]
Chlorides for Reinforced concrete	500 1000	[10,20,21] [8,72]

Constituent	Tolerable Limits	References
Zinc	100 500 600	[72] [11] [61]
Copper	500 600	[11] [61]
Lead (Pb)	100 500 600	[72] [11] [61]
Manganese	500 600	[11] [61]
phosphate	100	[66, 72]
Nitrates	500	[72]
Sugars	100	[66,67,72]
Turbidity	2000	[17]
H2SO4	6250	[17]
HCl Oil and Grease	10150 50	[24] [66,67]

Conclusions

The ideal pH range in mixing water for concrete is slightly basic i,e., between 7.2 and 7.6.

The total solids should be equal to sum of organic solids and inorganic solids or suspended solids and dissolved solids. Except pH, all constituents of mixing water of concrete should be equal to total solids. But it is not matched in any code.

Alkalinity due hydroxides has to be found out in mixing water for plain and reinforced cement concrete.

Acidity due to carbon dioxide and minerals has to be evaluated separately in mixing water for plain and reinforced cement concrete.

Limit of a sulphate and sulphates in a combination has to be evaluated in mixing water for plain and reinforced cement concrete.

Limit of a chloride and chlorides in a combination has to be evaluated separately in mixing water for plain and reinforced cement concrete.

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References

[1] S.R. Kshirsagar, Water for the 21st century, Journal of Indian Water Works Association 2000; 32:91-96.
[2] P.K. Mehta, JM. Paulo Monteiro, Concrete: Microstructure, Properties, and Materials, 3rd ed. McGraw-Hill Professional; 2005
[3] A.M. Neville, Water, Cinderella ingredient of conctrete. Concr Int Am Concr Inst 2000; 22(9):66-71.
[4] A. Neville, seawater in the mixture. Concr Int Am Concr Inst 2001;23(1):48-51
[5] K. Thomas, WEA Lisk. Effect of sea water from tropical areas on setting times of cements Mater. Struct 1970:3:14:101-105.
[6] AASHTO T 26-79. Standard method of test for quality of water to be used in concrete.
[7] ACI Committee 318-89. Building code requirements for structural plain concrete, ACI Manual of Concrete Practise, Part 3: Use of concrete in buldings, American Concrete Institute, Detriot.
[8] ASTM C94 – 1992. Standard specification for ready-mixed concrete, American society for testing and materials, Philadelphia.
[9] Standard Testing Bureau, Standard specification for mixing water of concrete, CNS 13961, Department of Economic Affairs , Taiwan, 1998.
[10] A.M. Neville, Properties of Concrete 3rd Ed,. Pitman, London, 1981.
[11] S. Mindess, JF. Young. Concrete.Prentice Hall,New Jercy,1981.
[12] PK. Mehta, Concrete, Structure, properties and materials, prentice-Hall, Inc,Englewo Cliffs, NJ, USA 1986.
[13] VK. Raina, Concrete for Construction:Facts and Practise Tata McGraw-Hill,New Delhi,India, 1988.
[14] J.J. Wadell, JA. Dobrowski, Concrete Construction Handbook .McGraw-Hill Inc 1993.
[15] S.H. Kosmatka, WC. Panarese, Mixing water for concrete, design and control of concrete mixtures. 6th Canadian. Portland cement Association 1995: 32 – 35.
[16] O.Z. Cebeci, IS. Saatci. Domestic sewage as mixing water in concrete, ACI Material Journal 1989: 86:503 -506.
[17] D.A. Abrams, Tests of impure waters for mixing concrete. In proceedings of the American Concrete institute, ACI, 1924: 20:442-486.
[18] A.M. Neville, Properties of concrete , fourth ed.,Longman Group ,England ,1995:182-184.
[19] Chineese Institute of Civil and Hydraullic Engineering, Construction Codes of Concrete Engineering, Sci.and Tech .Pub.,Taipei,1999.
[20] BS 3148-1980.Method for test for water for making concrete. London: British standard institute.
[21] IS 456- 2000. Plain and reinforced concrete-code of practice, New Delhi: Bureau of Indian Standards.
[22] Waddell, J. Joseph, Practical Quality Control for Concrete ,McGraw-Hill Book Co.,New York ,1962:396
[23] Popovics, Sandor. Concrete Making Materials, New York, McGraw-Hill Book: 1979:370.
[24] H.H. Steinour, Concrete mix water –how impure can it be ? J.PCA Res.Dev.Lab.1960:2:3: 32-50
[25] Portland Cement Association, principles of Quanlity Concrete, John Wiley and Sons, New York 1975: 312.
[26] W.J. McCoy, Mixing and curing water for concrete, ASTM Sp.Tech.publ.No.169B: 1978: 765-773.
[27] F.S. Mujahed, Properties of concrete mixed with red sea water and its effects on steel corrosion .Unpublished M.S.

Thesis, Jordan University of science and Technology Jordan 1989.
[28] O.A. El-Nawawy, S. Ahmed, Use of treated effluent in concrete mixing in an arid climate. Cem Concr Compos 1991; 13:2:137-41.
[29] A.R. Chini, L.C. Muszyasti, P.S. Ellis, Recycling process water in ready-mixed concrete operations. Final report submitted to the Florida Department of Transportation, University of Florida, Gainsville,February 1999:134.
[30] R. Taha, A. Al-Rawas, Al-Oraimi, H. Hassan, M. Al-aghbari, The use of brackish and oil contaminated water in road construction, Environmental and Engineering Geoscience 2005; XI:2: 74-150.
[31] R. Taha, A S. Al-Harthy, KS. Al-Jabri, Use of production and brackish water in concrete. Proceedings International Engineering Conference on Hot Arid Regions (IECHAR), Al-Ahsa, Kingdom of Saudi Arabia, 2010: 127-132.
[32] Al-Jabri K S, Taha R, Al-Saidy A H. Effect of using non fresh water on the mechanical properties of cement mortars and concrete. Proceedings the third international fib congress and PCI annual convention & Exhibition, Washington D C, USA 2010: May 29 – June 2.
[33] B. C. Doell, Effect of algae infested water on the strength of concrete, J.Am.Concr.Inst 1954: 51: 333-342.
[34] A.A. AI-Manaseer, MD. Haung, KW. Nasser, Compressive strength of concrete containing fly ash ,brine,and admixtures , ACI Master .J.1998:85:2: 109-119.
[35] G.E. Troxell, H.E. Dams, J.W. Kelly, Composition properties of concrete 2nd Ed. McGraw Hill, Inc. New York, N.J, 1968.
[36] J.J. Waddell, Concerte construction handbook. 2nd Ed. McGraw Hill, Inc., New York, N.Y, 1974.
[37] M.C. Bailey, Seweraga and sewage treatment in Dubai.Middle East water and Sewage 1980:161-170.
[38] H.E. Davis, G.E. Troxell, G.F.W. Hauck, The testing of engineering materials, McGraw Hill Books Co, New York, 1982.
[39] S. Popovics, Y. Simeonov, G. Bozhinov, N. Barovsky, Durability of reinforced concrete in sea water. Corrosion of Reinforcement in Concrete Construction,ed.Alan P. Crane.Ellis Horwood Ltd,London,1983:19-38.
[40] J.H. Tay, WK. Yip, Use of reclaimed water for cement mixing. J. Environ. Engg 1987: 113:5: 1156-60.
[41] P.H. Ferguson, JE. Brecem, JO. Jirsa, Reinforced Concrete Fundamentals. 5th edition, John Wiley and Sons ,New York,1988.
[42] Construction Industry Research and Information Association,The CIRIA Guide to Concrete Construction in the Gulf Region,CIRIA,London,1984.
[43] Concrete in Hot Countries, STUVO, the Dutch member group of FIP, Hertogendosch,1986: 44 – 45.
[44] Portland Cement Association .Design and control of concrete Mixtures; PCA: Skokie,IL,1990.
[45] J. Borger, RL. Carrasquillo, DW. Fowler, Use of recycled wash water and returned plastic concrete in the production of fresh concrete. Adv Cem Based Mater 1994; 1:267-74
[46] W. Fu, ZB. Wang In:The new technology of concrete engineering. Beijing: The Publishing House of Chineese Architectural Industry; 1994:56-59
[47] N. Su, Y H. Wu, Effect of Magnetic Water on the Engineering properties of concrete containing granulated blast-furnace slag. Cem Concre Res 2000; 30:599-605.
[48] Q. Yu, S. Sugita, K. Swayama, Y. Isoijma, Effect of Electron Water curing and Electron charge curing on concrete strength. Cem Concre Res 1998; 28:1201-1208.
[49] N. Su, KC. Lee, Effect of Magnetic Water on the Mechanical properties and micro–structures of concrete. J Chin Inste Civ Hydraul Eng 1999: 11:3: 175-180.
[50] Su. Nan, Wu. Yeong-Hwa, Mar. Chung-Yo, Effect of magnetic water on engineering properties of concrete containing granulated blast furnace slag ,Cement and Concrete Reaserch, 2000:599-605
[51] Su. Nan, Wu. Chea-Fang, Effect of magnetic field treated water on mortar and concrete containing fly ash. Cement &Concrete Composites 2003:25:681–688.
[52] F. Sandrolini, E. Franzoni, Waste wash water recycling in ready-mix concrete plants. Cement and Co,Research 2001:31:485-489.
[53] HY. Moon, Properties of cement matrix mixed with ready-mixed concrete sludge and residual water, Hanyang University of Korea, ICCMC/IBST 2001: 519-25.
[54] J. Selih, E. Milost, A. Cuznar, Use of recycled rubble-based aggregate and recycled water in concrete proceedings, International Symposium on Recycling and Reuse of Waste Materials, University of Dundee, Scotland, 9-11 September, 2003.
[55] Nan Su, buquan Miao, Fu-Shung Liu, Effect of wash water and underground water on properties of concrete, cement concrete research 2002: 32:777-782.
[56] Ibrahim Al-Ghusain, Mohammad J Terro, Use of treated wastewater for concrete mixing in Kuwait, Kuwait J. Sci. Engg 2003: 30:1: 213–227.
[57] AS. Al-Harthy, R. Taha, J. Abu-Ashour, K. Al-jabri, S. Al-Oraimi, Effect of water quality on the strength of flowable fill mixtures, Cment and concrete Composites 2005: 27; 33-39.
[58] H. Kuosa, Recycling of concrete, sludge and water in the concrete industry, proceedings, 18th BIBM International congress, 11-14 May, Amsterdam 2005.
[59] B. Chatveera, P. Lertwattanaruk, N. Makul, Effect of sludge water from ready -mix concrete plant on properties and

durability of concrete . Cement and concrete composites 2006: 28:441-450.
[60] I.V. Ramana Reddy, N.R.S Prasad Reddy, G. Reddy Babu, B. Kotaiah and P. Chiranjeevi, Effect of biological contaminated water on cement mortar properties, The Indian Concrete Journal 2006: 80:13-19.
[61] G. Reddy Babu, H. Sudarsana Rao, I.V. Ramana Reddy, Effect of metal ions in industrial wastewater on setting, strength development and hardening, The Indian Concrete Journal 2009: 83: 43-48.
[62] S.O. Ekolu, A. Dawneerangen, Evaluation of recycled water recovered from a ready mix concrete plant for reuse in concrete. J S Ar. Inst. Civ. Eng. 2010: 52: 2.
[63] K.S. Al-Jabri, AH. Al-Saidy, R. Taha, AJ. Al-Kemyani, Effect of using wastewater on the properties of high strength concrete, The twelfth asia-pacific conference on structural engineering and construction, procedia Engineering 2011:14:370-376.
[64] B. Madhusudana Reddy, G. Reddy Babu, I.V. Ramana Reddy, effect of lead in mixing water on the properties and durability of high strength cement mortar, The Indian Concrete Journal 2013: 87; 45-51.
[65] G.R. White, Concrete technology. Von Nostrand Reinhold, New York,N.Y 1977.
[66] AS 1379, Specification and supply of concrete Standards Australia, 2007
[67] NZS 3121, Specification for Water and Aggregate for Concrete,New Zealand Standards 2002
[68] SANS 51008, Mixing water for concrete, South African National Standards 2006
[69] D.A. Abrams, In Experimental Studies of Concrete; Structural Materials Reaserch Laboratory, Lewis Institute: Chicago 1925.
[70] M. Fintel ,Handbook of concrete Engineering.2nd Edition, Van Nostrand Reinhold Co., New York, p.179.
[71] I. Soroka, Portland cement paste and concrete. 2nd Ed., MacMillan press, London, England 1979.
[72] EN 1008, Mixing water for concrete. Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete, 2002.
[73] F.K. Kong, R.H. Evans, E. Cohen, F. Roll, Handbook of structural concrete. Pitman Advanced Publishing programme, London, 1983.