

# Quality of Water for Making Concrete: A Review of Literature

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**Abstract-** This paper reviews the literature related to quality of water for making concrete. The allowable limits of physical and chemical impurities and the test methods of their evolution are compiled. The limits of impurities as per Indian, Australian, American and British standards are represented. From the literature it is seen that, the reaction between water and cement affects the setting time, compressive strength and also lead to softening of concrete. All the impurities may not have adverse effect on the properties of concrete. The use of impure water for concrete mixing is seen to be favorable for strength development at early ages and reduction in long term strength.

**Index Terms-** Alkalinity, compressive strength, flexural strength, magnesium chloride, setting time, pH value.

## I. INTRODUCTION

Concrete is one of the most durable construction material and Cement is one of the most energy intensive structural materials in concrete. The principal considerations on the quality of mixing water are related to performance in fresh as well as hardened state. The quality of the water plays an important role in the preparation of concrete. Impurities in water may interfere with the setting of the cement and may adversely affect the strength and durability of the concrete also. The chemical constituents present in water may actively participate in the chemical reactions and thus affect the setting, hardening and strength development of concrete. In addition to that, health issues related to the safe handling of such water must be considered. The suitability of water can be identified from past service records or tested to performance limits such as setting times and compressive strength and durability test. Limits are specified for mixing water with their constituents such as total alkalis, chloride sulfate etc. Biological treatment and pathogen reductions are also ensure safety in handling of reclaimed water and saline water.

F M Lea [1] specified that, pure water decomposes the set cement compounds, by dissolving the lime and alumina from cement. This action of leaching is continues and then after slows down till the water is able to pass continuously through the mass of concrete. Water which are acidic owing to the presences of uncombined carbon dioxide, of organic or inorganic acids, are more aggressive in their action, the degree and rate of attack increases as the acidity increases. In general, acid solutions which attack cement mortars or concrete by dissolving part of the cement do not cause any expansion, but progressively weaken the material by removal of cementing constituents forming soft and mushy mass.

Paulo J.M. and et al [4] specify that, any water with pH value less than 12.5 may be aggressive in their action because of, a reduction of the alkalinity of the pore fluid would, eventually lead to removal of the cementitious material. However, the rate of chemical attack will be function of the pH of the aggressive fluid and the permeability of concrete. When the permeability of concrete is less and the pH of the fluid is above 6, the rate of chemical attack is too slow. Again the chemical attack on concrete results into detrimental physical effects, such as porosity, decrease in strength, cracking and breaking into pieces.

There are various existing and new sources of water available which may be suitable for complete or partially replacement of potable water for concrete making. It includes reclaimed water, groundwater, treated water from sewer and water from ready mix concrete plant etc. Due to the shortage and scarcity of water in many part of the world and especially in arid regions like Qatar and Dubai, water authorities are moving towards identifying new sources of water. In these countries, treated effluents are being used for irrigation purpose as well as for concrete mixing, curing and washing of aggregates also. Water from stream, river and even sea is also suitable, if it not contain brackish matter. One of the facts that in arid countries, desalinated water blended with brackish ground water used for concrete making purpose and for making concrete slurry also.

Some important definitions;

- a) Potable water: Water which is suitable for consumption of human being.
- b) Recycled water: Water which is treated up to acceptable limit which is suitable for its intended use.
- c) Blackish water: Waste water generated from toilet, urinals which are directly contaminated with human excreta.
- d) Gray water: Waste water from wash basins, showers, laundries and kitchen.

## II. LITERATURE REVIEW

Limits and guidelines from standards;

- 1) IS 3025-1984[5] Methods of sampling and test for water and waste water.
- 2) IS 456-2000[6] Plain and reinforced concrete - code of practice.
- 3) AS 1379-1997[7] Specification and supply of concrete.
- 4) ASTM C94-1996[8] Specification for ready mixed concrete.
- 5) ACI 318M-08[9] Building code requirements for structural concrete and commentary.
- 6) ASTM 1602M-06[10] Standard test method for mixing water used in the production of hydraulic cement concrete.
- 7) EN 1008-2002(E)[11] 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.

IS 3025[5] recommended that, testing of water play an important role in controlling the quality of cement concrete work. Systematic testing of the water helps to achieve higher efficiency of cement concrete and greater assurance of the performance in regard to both strength and durability. Water is susceptible to being changed due to physical, chemical or biological reactions which may take place between at the time of sampling and analyzing. Hence it is necessary to test water before used for cement concrete production.

Samples should be collected, as far as possible, from midstream at mid depth, Sites should be selected such that marginal changes in water observed with naked eyes, where there are major river discharges or obstructions occurred, sample from 100m away of the discharge point in downstream side is taken for small streams. In case of long length river there should be at least three fixed sampling locations along the cross-section. Sampling locations can be fixed with reference to significant features

In case of waste water from sewers and narrow effluent channels, samples should be drawn from one third water depths from the top without skimming the top or scraping the bottom. Velocity of flow at the sampling point should be sufficient to prevent the deposition of solids. Sample should be drawn gently without causing aeration or liberation of dissolved gases. In most cases, sewage flows are intermittent and hence collection of sample at every hour is necessary. Waste waters usually decompose rapidly at room temperature, therefore, certain test setups, such as dissolved oxygen, sulfides, residual chlorine, nitrite and pH should be fixed at site. For certain other tests, preservatives should be added immediately to individual sample.

AS 1379[7] recommended that, mixing water shall be drawn from a source of acceptable quality. Acceptable quality of water is, water from ready mix concrete plant in washout operations, may be used as mixing water if it is stored such as to prevent contamination by deleterious matters to concrete and the water drawn from the storage outlet. Acceptable quality is identified from past service records or tested to requirements given in Tables 3 and 4 in the standard.

ASTM C94[8] recommended that, mixing water comprises, water and ice added to the batch, water occurring as surface moisture on the aggregates and, in the case of truck mixers, any wash water retained in the drum for use in the next batch of concrete. Water shall conform to ASTM C1602, which defines sources of water and provides requirements and testing frequencies for qualifying individual or combined water sources. In any case where the requirements of the owner differ from the specifications, the owner's specification shall be provided. ASTM C94 permits the use of non-potable water or water from concrete production operation in ready mix concrete plant, the limits qualified to meet the requirements and optional limits summarized in code. The levels of impurities permitted in the wash water should be below the maximum concentration criteria provided in standard.

EN 1008[10] recommended the requirements for water, suitable for making concrete conforming to EN 206-1 and describes methods for assessing its suitability. This standard considers, the use of potable water, water recovered from processes in the concrete industry, water from underground sources, natural surface and industrial waste water for reinforced concrete, and seawater or brackish water for production of concrete without reinforcement or with other embedded metal. Sewage water is not suitable for production of concrete. The requirements for water are summarized in standard comprising preliminary assessment, chemical properties, setting time and strength development. Standard provides specific requirements for the use of water recovered from processes in the concrete industry.

Following dissolved chemical impurities and their limits and possible hazardous effects on concrete; are not available in Indian, Australian, American and British standards[3]

- a) Natural water or fresh water rarely contains more than 2000 ppm of dissolved solids, and is generally suitable for making concrete.
- b) Water contaminated with industrial wastes, but free of suspended solids, is also suitable at low concentrations for making concrete.
- c) Much larger contents of the impurities, in natural water can be tolerated except for the alkali carbonates and bicarbonates which may have significant effects even less than or equal to 2000 ppm.
- d) Other inorganic impurities of possible industrial origin, that may be detrimental at moderate concentrations those are, sulfides, iodides, phosphates, arsenates, borates, and compounds of lead, zinc, copper, tin and manganese are adversely affect concrete properties.
- e) Organic impurities also likely to change concrete properties, especially present in sugar.

Table I: Recommended limits and possible hazardous effects of dissolved chemical impurities in water [3]

Impurities	Limit	Remarks
NaNO <sub>3</sub> and KNO <sub>3</sub>	No limit available	Sodium and potassium nitrates give strength little inferior to those obtained with sodium chloride.
CaSO <sub>4</sub>	No limit available	Water saturated with calcium sulfate is satisfactory for the liquid phase in cement paste which is normally saturated or even super-saturated with this compound.
Ca(NO <sub>3</sub> ) <sub>2</sub>	1.7% weight of cement	Calcium nitrate added 1.7% weight of cement accelerates setting time and strength reduction.
Na <sub>2</sub> SO <sub>4</sub> , MgCl <sub>2</sub> , MgSO <sub>4</sub>	10,000 ppm	1% concentration of these common ions, exclusive of carbonate and bicarbonate, could be present without much effect on strength.
(FeSO <sub>4</sub> )	No limit available	In mix water, if 0.5, 1, 2, and 4 % weight by water shows 28 days and 3 years tensile strengths which is exceeding 10 and 15% of control specimens.
Zinc oxide	0.01% weight of cement	No significant effect but 0.1% strongly retarded setting time and lowered strength.
Ammonium ion	No limit available	Ammonium chloride increased strength. 0.4, 0.8 and higher percentage by weight of water of ammonium nitrate give same strength as with similar percentage of NaCl in water for making concrete.
Tannic acid	0.5% weight of water	No effect on strength but may have a considerable effect on setting time of concrete.

Following tables show difference in codal values, provisions of impurities in mixing water;

Table II Different Codal values and provisions for the assessment of pH value of water in concrete [5, 6, 7, 8, 9, 10, 11]

Parameter	Standards	Limits	Provision / Remarks
pH value	IS456-2000[6]	≥6.0	- Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel.
	AS 1379[7]	>5.0	-Water recycled from ready mix concrete mixer, from washout operations may be used as mixing water if it is first stored in accordance with Clause 3.2.3 and the water drawn from the storage outlet is of acceptable quality. -Testing method is accordance with AS/NZS 1580.505.1
	ACI 318M-08[9]	-	Any natural water that is potable and has no pronounced taste or odour is satisfactory as mixing water for making concrete.
	EN 1008[11]	≥4.0	-Water for use in concrete shall conform to the requirements of clause no. 4.2, 4.3.1, 4.3.2 and 4.3.3. The water shall also conform to the chemical requirements as per clause no. 4.3.4

F. M. Lee [1] described that, water which is acidic owing to the presences of uncombined carbon dioxide, of organic or inorganic acids are more aggressive in their action, the degree and rate of attack increasing as the acidity increasing. Acid solutions which attack cement mortars or concretes by dissolving part of the set cement do not cause any expansion, but progressively weaken the material by removal of the cementing constituent and ultimately soft and mushy mass is remains.

A. M. Neville[2]specified that,drinking water may be unsuitable as mixing water when the water contains a high concentration of sodium or potassium which lead to danger of alkali-aggregate reaction. While the use of potable water is generally safe, water not fit for drinking may also be satisfactorily used in making concrete. As a rule, any water with pH of 6.0 to 8.0 which does not taste saline or brackish is suitable for use. Colour and odour do not necessarily mean that, deleterious substances are present in water. Natural waters that are slightly acidic are harmless, but water containing humic or other organic acids may adversely affect the strength of concrete.

Y. F. Fanand etal[12]performed an experiment on compressive strength of corroded concrete, with accelerated corrosion test is performed. Corrosive solutions, including hydraulic acid solutionwith pH 2 and 3, NaCl solution 10% and 20% of water, Na<sub>2</sub>SO<sub>4</sub> solution 10% and 20% of water, are used as the corrosive medium. Then mechanical property of all the corroded specimens is tested respectively. Mechanical properties of the corroded specimens those are compressive strength, stress-strain relation, and elastic modulus are tested.

- Specimens exposed to hydraulic acid solution: Specimen being corroded more severely, the stress-strain curve become more gently; the compressive strength and elastic modulus of the specimens will decrease with exposure days. The failure mode of tensile strength of corroded specimen is different from that of un-corroded specimen.
- Specimens exposed to sodium chloride and sodium sulfate solution:- At the initiation of corrosion state, the compressive strength is slight increase, and the increase amount of the compressive strength is related to the concentration of solution; with the severe corrosion of the concrete, the strength will decrease.

D. O. McPolinand etal[13]have carried out an investigation on, measurement of the degree of carbonation and changein pH value. The mortars were casted using ordinary Portland cement, pulverized fuel ash, ground granulated blast-furnace slag, metakaolin, and microsilica. The mortars were exposed to a carbon dioxide-rich environment 5% CO<sub>2</sub>by weight of cement to accelerate carbonation. The resulting carbonation was measured by using phenolphthalein indicator and thermo-gravimetric analysis. It indicates that, the decrease in pH value is not as much as would be expected for 10 weeks exposure in 5% carbon dioxide environment curing. This was happened, due to the high cementitious material content; there were more calcium hydroxide and other compounds which controls pH of water such as, potassium and sodium oxides. The pH of the mortar is constant at the depth where carbon dioxide not able to penetrated in concrete. And hence the value of pH and degree of carbonation is a function of the mix design.

S. Mukhtar Homam and etal[14]carried out an investigation to study the effect of durability of FRP concrete CFRP and GFRP. Environmental parameters to which the specimens were subjected those includes freeze-thaw cycling and temperature variation with pH 10, pH 12 and pH 13.7 concentrations NaOH solutions. Specimens comprised FRP wrapped concrete cylinders and FRP bonded concrete prisms. The tests carried out on the specimens examined the influence of various environmental conditions on the confining effects of FRP wraps and performance of FRP-to-concrete bonds. Results indicate that, the specimen exposed to low alkaline environments pH 10 has minimum effects on the confining properties.However at high alkaline environment, bond strength and freeze-thawing are adversely affected.

Table II (b): Different Codal values and provisions for the assessment of compressive strengthof concrete [5, 6, 7, 8, 9, 10, 11]

Parameter	Standards	Limits	Provision / Remarks
Compressive strength	IS 456-2000[6]	≥85% of the mean compressive strength of control specimen shall be taken.	-The test results of the sample shall be the average of the strength of three specimens. The individual variation should not be more than ±15 percent of the average. If more, the test results of the sample are invalid.
	AS 1379[7]	≥90% of the mean strength of the control samples prepared with water from a stable drinking water supply.	7day and 28day compressive strength of concrete made with water from a source with no service record. Test procedure accordance with AS1012.9
	ASTM C94[8]	≥90% of the mean strength of the control samples prepared with distilled or Potable water.	-The mean 7day compressive strength of the mortar or concrete samples prepared with the water which must be controlled sample. Test procedure accordance with C109 <sup>A</sup> .
	EN 1008[11]	≥90% of the mean strength of the control samples prepared with distilled or de-ionised water.	-The mean 7day and 28day compressive strength of the mortar or concrete samples Prepared with wash water.

E. Arunakanthi and etal[15]carried out an experimental investigation to study, the effect of aggressive chemical environment on high performance concrete with metakaolin.Ordinary portland cement is replaced 20% by weight with metakaolin and aggressive chemical

environment is simulated by subjecting the concrete to different concentrations of Hydrochloric acid 50mg/L, 100mg/L, 400mg/L and 800mg/L in deionised water. Compressive strengths and split tensile strengths were determined at 7, 28 and 90 days. The results indicate that the compressive strength and split tensile strength decrease with the increase in concentration of HCl when compared with concrete without HCl in mixing and curing water.

Semsi Yazici and etal[16] studied the effect of temperature and time, on the mechanical behavior of concrete. The concrete mixtures are produced using two different water/cement ratios; 0.4 and 0.6 with standard 28 days curing. After standard curing period, specimens are dried in a furnace at 105°C for 4hrs. Then the specimens are kept in laboratory for 1 day with different exposure temperatures 300°C, 600°C and 900°C for 1,3 and 5hrs. Then compressive strength and split tensile strength are determined. It was concluded that, compressive strength and split tensile strength of specimens are reduced after the high temperature and time exposure. Compressive strength increases with lesser water to cement ratio.

N. Smaoui and etal[17] have studied, effect of increasing the alkali content of concrete with 0.6% and 1.25% of Na<sub>2</sub>O<sub>3</sub> by weight of the cement mass by adding of NaOH to the water. Results show that, there are harmful effects on mechanical properties such as compressive strength and freeze-thawing strength of concrete made with a water-to-cement ratio of 0.41. Shrinkage tests show that, the low-alkali concrete shrinks more than the high-alkali concrete. Freeze and thaw tests performed on air-entrained concretes show that, the two concrete specimens resist more to freezing and thawing. When examined under the scanning electron microscope, the hydrates in the two concrete specimens present similar microstructure; however, the high-alkali concrete shows a more reticular and porous micro-texture, which results in the reduction of compressive strength.

K. Srinivasa Rao and etal[18] have investigated; the effect of elevated temperatures up to 950°C on compressive strength of high strength concrete of M<sub>60</sub> grade using fly ash based Pozzolona Portland Cement. High strength concrete cube specimens were exposed to different temperatures of range 50°C to 950°C in intervals of 50°C for different durations of 1,2 and 3 hours. After exposing the specimens to elevated temperatures, they were tested for their compressive strength in hot state. Then the effect of elevated temperatures on compressive strength of high strength concrete was tested. Results shows, specimen when exposed to temperatures in the range of 100°C to 250°C, the concrete shows a gradual increase in compressive strength irrespective of durations of exposure to temperatures. This increase in compressive strength may be attributed to the effect of accelerated curing of concrete. Between 250°C and 350°C, more or less the same compressive strength is maintained for all durations of exposure. Beyond 400°C the compressive strengths was observed to have gradually decreased up to a temperature of 700°C. Rapid decrease in compressive strength was observed in the temperature range of 700°C and 950°C. This may be attributed to the fact that the high strength concrete possesses high density and less permeability. When it is exposed to high temperatures, the pore pressure developed inside the cubes will try to expel out and leads to the formation of cracks on the surface of concrete cubes causing spalling of concrete.

Table II (c): Different Codal values and provisions for the assessment of setting times of concrete [5, 6, 7, 8, 9, 10, 11]

Parameter	Standards	Limits	Provision / Remarks
Setting times	IS 456-2000[6]	≥30min. ≤10hrs.	-Initial setting time. -Final setting time. Test procedure accordance with IS 4031- Part 5.
	AS 1379[7]	60 min. earlier than control sample. 90 min. later than control sample.	-Initial setting time. -Final setting time. Test procedure accordance with AS1012.18
	ASTM C94[8]	1:00 hrs earlier than control sample. 1½ hrs later than control sample.	-Initial setting time. -Final setting time. Test procedure accordance with C191 <sup>A</sup> .
	EN 1008[11]	Initial set ≥1 hrs Final set ≤ 12 hrs	-With both not differing by more than 25%. Specimens made with distilled or deionised water. Test procedure accordance with clause no. 6.1.4 of same standard.

H.Y.Ghorab, and etal[19] have investigated; the effect of natural available water on setting time of hydraulic cement. From studies, it is reported that, setting time of OPC mostly affected by the water type. The initial setting time reduced by 4% with use of Nile river water and approximately 25% with the ground and sea water when compare with tap water.

V. Venkateswara Reddy and et al [20] studied the effect of alkalinity on setting time and strength development of fly ash concrete is assessed under the laboratory conditions. The results indicate that, the initial and final setting times either retarded or accelerated depending upon the type of alkalinity imparted by Sodium carbonate or Sodium bi-carbonate. Sodium carbonate when present in water accelerated both the initial and final setting time when its content is equal to 6 gm/L and 4 gm/L respectively. Sodium bi-carbonate when present in water retarded both the initial and final setting time when its content is equal to 4 gm/L and 6 gm/L respectively. The decrease of compressive strength and tensile strength with increase in concentration of Sodium carbonate and Sodium bi-carbonate with concentration more than 6 gm/L and 10 gm/L respectively.

G.L. Low and et al [21] aim of this investigation is to define, the limits and extent to which cement-based slurry water from the concrete batching plant can be recycled and totally reused for making concrete without the need for further treatment. The study focused on the effects of using such mixing water on the fresh and hardened properties of concrete with reference to acceptance criteria of existing standards ASTM C94-98c, BS 4550: 1978. Results showed that concrete produced with slurry water was able to meet the performance criteria in terms of compressive strength, setting time and drying shrinkage, when the specific gravity of the slurry water used was less than 1.03 and the pH of the water sample in between 12.3 to 13.3.

G.D. Stefanou and Ch. Larsinos [22] performed an experiment, to study the quantity of mixing water as a function of setting time of concrete. The study was carried out as per ASTM C-403-70. Four mixes were prepared; all quantities were kept constant except for water which was increased by 15 kg for first three mixes for last mix the interval was 20 kg. The result obtained from experimental work showed that, increased in water causes lengthening of the setting time also at the start and end of setting time is a constant difference of 20-30 min. for every 15 kg of water added.

Table II (d): Different Codal values and provisions for the assessment of Suspended solid matter and SO<sub>4</sub> in water [5, 6, 7, 8, 9, 10, 11]

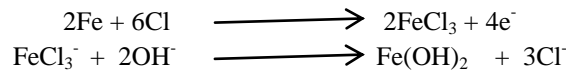
Parameter	Standards	Limits	Provision / Remarks
Suspended solid matter	IS 3025 - Part 17 [5]	≤ 2000 mg/L	-Gravimetric method is used for the determination of non-filterable residue.
	AS 1379 [7]	-	-Materials that are not compatible shall not be used in the same volume of plastic concrete or if used.
	ASTM C94 [8]	≤ 50,000 mg/L	-Optional requirement of total solids by mass. Test method AASHTO T26
	EN 1008 [11]	≤ 1% of total aggregate	-Recommended value
SO <sub>4</sub>	IS 3025 (Part 24) [5]	400 mg/L	-Sulfate in SO <sub>3</sub> form
	AS 1379 [7]	≤ 500 mg/L of cement.	-Specified as a total limit for concrete.
	ASTM C1602M [10]	≤ 3000 mg/L	-Sulfate as in SO <sub>4</sub> form. Test method as per D516
	EN 1008 [11]	≤ 2000 mg/L	-Tested in accordance with 6.1.3 and expressed as SO <sub>4</sub> <sup>2-</sup>

Madhusudana Reddy. B and et al [22] have investigated the effect of lead (Pb<sup>+</sup>) present in mixing water on compressive strength, setting times, soundness and sodium sulfate attack of high strength cement mortar. Cement mortar specimens were cast using deionised water and known concentration of lead i.e. 10, 50, 100, 500, 1000, 2000, 3000, 4000 and 5000 mg/L whereas cement mortar specimens casted using deionised water used for reference purpose. On comparison with reference specimens, at higher concentrations of lead in water, test samples had shown considerable loss of strength, and also their setting times had significantly increased. However, at 2000 mg/L concentration of lead, the compressive strength and setting time marginally increased.

Table II (e): Different Codal values and provisions for the assessment of Cl<sup>-</sup> content in water [5, 6, 7, 8, 9, 10, 11]

Parameter	Standards	Limits	Provision / Remarks
Cl <sup>-</sup> content	IS 3025 -Part 32[5] IS 456[6],	≤2000mg/L	Concretes that do not contain reinforcement, tendons, ducts, embedded items.
		≤500 mg/L	-For concrete Containing embedded steel
	AS 1379[7]	≤800 mg/L	-Concrete contains reinforcement, tendons, ducts, embedded items or other items that require protection.
	ASTM C1602M[10]	≤500 ppm	- Prestressed concrete.
		≤1000 mg/L	- Reinforced concrete.
	EN 1008[11]	≤500 mg/L	-Prestressed concrete/grout.
		≤ 1000 mg/L	-Reinforced concrete or embedded metal.
		≤ 4500 mg/L	-Without reinforcement or embedded metal.

M. Pakshir and S. Esmaili[23]carried out an investigation to study, the influence of different cations and chloride ions on the corrosion of reinforced concrete. There are two different mixes casted. In first mix, different concentrations of calcium and sodium chlorides were mixed with water and there corrosion activities studied with normal and accelerated corrosion process. In second mix, similar concrete specimens were exposed to solution of different concentration of chloride ions. Results were observed that, rise of concentration of sodium chloride, increase susceptibility to corrosion. The specimen in 0.1% NaCl solution shows maximum resistance to corrosion after 60 days of exposure.Chloride ion present in the water can act as a catalyst for the oxidation of iron through formation of the FeCl<sub>3</sub> complex which is unstable and can be drawn into the solution, where it react with available hydroxide ions to form Fe(OH)<sub>2</sub>.This results the release of Cl<sup>-</sup> ions back into the solution and consumption of hydroxyl ions, as shown in following reaction;



Because of Fe(OH)<sub>2</sub> in solution which results lower the pH, this reduces the oxide film and allows easier penetration of chloride ions, which ultimately results to increase in corrosion.

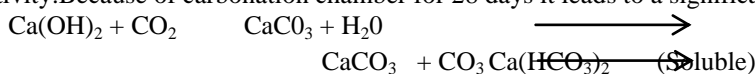
V. Venkateswara Reddy and etal[24]havestudied the effect of Magnesium chloride on ordinary portland cement concrete.The ordinary portland cement concrete was produced with MgCl<sub>2</sub> dosage of 200, 500, 1000, 1500 and 2000 mg/L and deionised water was used in concrete mix M<sub>20</sub>and M<sub>50</sub>. In addition to this, control specimens were prepared with deionised waterwithout MgCl<sub>2</sub> for comparison. The compressive and tensile strengths were evaluated for 28 and 90 days. The results show that, as the MgCl<sub>2</sub> concentration increases, the compressive strength increases and tensile strengths decrease.Following reaction taken place between MgCl<sub>2</sub> and calcium oxide;



MgCl<sub>2</sub> solution reacts with slaked lime to form CaCl<sub>2</sub> and Mg(OH)<sub>2</sub>. The formation of soluble CaCl<sub>2</sub> leads to initial strength loss. As Mg(OH)<sub>2</sub> is insoluble in water, its formation does not increase the porosity and the permeability of the system. Thus the formation of magnesium hydroxide (brucite) leads to loss of strength. Initial setting time and final setting time is retarded with increase in MgCl<sub>2</sub>, it is significant at 1500mg/L and 500mg/L respectively.

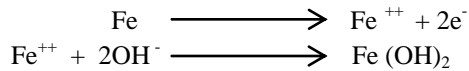
Carbonation of concrete by CO<sub>2</sub> ions, none of national or international standards provided limiting values or guideline for making concrete[5, 6, 7, 8, 9, 10, 11].

Peter A Claisse, Hanaa I Elsayad and Ibrahim G Shaaban [25]carried outan investigation to study, the effect of carbonation on the permeability and pore structure of concrete. Two concrete mixes with different water to cement ratios were prepared.Each prepared sample allow to both wet and dry curing and exposed in a carbonation chamber for up to 140 days.The carbonation chamber contained a 5% concentration of CO<sub>2</sub>. Prisms measuring 50 x 50 x 300 mm were cast for studying the degree of carbonation, and 150 mm cubes were cast for measuring the impermeability index, pore volume and compressive strength of concrete. The result shows that, strength and curing of concrete are the main factors affecting the impermeability index; depth of carbonation was higher for low strength and air-cured concrete. Carbonation reduces the permeability and porosity. The reduction was greatest in poor quality concrete. When compared with the other effects of carbonation the reduction in permeability is seen to be similar to the reduction in electrical resistivity.Because of carbonation chamber for 28 days it leads to a significant reduction in the permeability and porosity of concrete.



Carbonation of concrete is the chemical reaction between atmospheric carbon dioxide and the products of hydration of cement, particularly  $\text{Ca}(\text{OH})_2$  in accordance with the above reaction. However, it is now accepted that the other hydration products such as calcium silicate hydrate (C-S-H) and even the residual unhydrated cement compounds which are present in all concrete also cause carbonation of concrete.

V.M. Galande [26] said that, concrete is the shield for the reinforcement. The concrete protects the steel when concrete pH value is around 12. If the value is below 12 the protection gradually decreases, the value of 9.5 will not provide any protection to steel from corrosion. The free lime present in concrete is mainly responsible for protecting the steel by providing alkaline environment. When external agents like water, acids gases and other chemical compounds react with free lime present in concrete, free lime converted into different complex compounds. This results, either acidity or lowering alkalinity of concrete. If pH lower than 9.5 result the steel susceptible to corrosion. Carbon dioxide and chloride salts are the two agents responsible for steel corrosion. The chemical reaction is shown below;



JooHwa Tay and WoonKwong Yip [27] have studied effect of reclaimed wastewater on concrete properties. From this study, waste water from Jurong Industrial water works taken with 0%, 25%, 50%, 75% and 100% replacement of potable water. Water to cement ratio 0.6 and curing days 3, 7, 21 and 28 are considered for compressive strength testing. For studying long term effect of reclaimed waste water on compressive strength, two mixes are taken from potable water and other from 100% replacement of potable water with curing for 3 month, 6 month and 12 month. Result shows a general increase in compressive strength with increase in percentage of reclaimed wastewater ranges from 8% to 17%. The use of reclaimed wastewater for concrete mixing is seen to influence favorably the strength development of concrete at earlier age, for ages 3 month and beyond the effect was insignificant.

Ravindra Gettu and et al [28] have studied the corrosion behavior of steel in cracked ordinary portland cement and portland pozzolona cement concrete when exposed to chloride rich environment. Three water to cement ratio of 0.37, 0.47 and 0.57 and pre-cracked width of 0.2mm and 0.4mm were taken. Specimens of concrete with steel bar 12mm diameter placed at bottom with 20mm clear cover. Different tests conducted were chloride ion penetration and gravimetric weight loss. Results show that, chloride ion penetration of portland pozzolona cement was three times more than ordinary portland cement. The gravimetric weight loss of reinforcement in portland pozzolona cement is 50% less than that of ordinary portland cement.

Kunal Kupwade and Erez N. Allouche [29] have studied the durability of steel reinforcement made in geo-polymer concrete specimens, made with alkali-activated fly ash and ordinary portland cement in cyclic wet-dry chloride environment over a period of 12 months. Results show that, geo-polymer concrete specimens were found to exhibit lower chloride diffusion coefficient, chloride content and porosity compared with ordinary portland cement. It is proposed that, geo-polymer concrete serve as an effective substitute for ordinary portland cement concrete in marine environments or subjected to prolonged exposure to salts.

Pilar Alaejos and Miguel A. Bermudez [30] have studied the effect of sea water curing on properties of reinforced cement concrete. Different tests conducted are, compressive strength, porosity, chloride penetration rate and capillarity. The result shows that, sea water curing does not affect compressive strength, or the porosity of concrete specimens cast with sulfate resistance cement. However, it increases the chloride concentration at the concrete surface which results in hygroscopic effects and lead to water absorption and capillary suction. Chloride penetration coefficients are initially higher in sea water curing concretes, but as time increases the curve becomes constant.

### III. CONCLUDING REMARKS

Impurities present in water are reacting differently with different constituent of cement. These reactions mostly affect the setting time, compressive strength and may also cause straining of concrete surface. All impurities may not have adverse effects on the properties



of concrete. Some impurities react such that, net result may be harmless or improve concrete properties. Also impurities present in water varies depending upon places, time, environment and human interference. Hence it is difficult to draw a common conclusion for use of water for mixing and curing in concrete. The use of impure water for concrete mixing is seen to be favorable for strength development at early ages. However the general consensus is that, there is reduction in the long term strength of concrete. But with proper mix design and acceptable tolerance limit of impurities in water, it may be possible to use impure water in concrete mixing and curing also. On the other hand, there is a risk of steel corrosion in reinforced concrete, which is also a major concern for research.

Following conclusions are drawn from the review of literatures

- 1) Degree and rate of attack of corrosion of steel increases as pH value of water decreases. It was found that, the rate of corrosion is more below 3.0 pH value of water. Chlorine ions present in water form hydrochloric acid (HCl), can act as a catalyst for oxidation of steel in concrete. This results in formation of  $\text{Fe}(\text{OH})_2$  which allows for easier penetration of chloride ions and hence formation of corrosion.
- 2) There is reduction of compressive strength and split tensile strength of concrete with reduction in pH value of water.
- 3) There is reduction of bond strength and freeze-thawing action of fiber reinforced concrete with increase in pH value of water.
- 4) Presence of high alkali about 1% to 1.25% of  $\text{Na}_2\text{O}_3$  shows, minimum shrinkage of concrete and high freeze-thawing resistance.
- 5) Compressive strength of concrete increases when temperature is in between  $200^\circ\text{C}$  -  $250^\circ\text{C}$  because of accelerated curing of concrete. It was observed that, there is reduction in strength more rapidly at temperature ranges  $700^\circ\text{C}$  -  $900^\circ\text{C}$ .

In practice, the possible effects of various impurities in the mixing water are tested simply for their setting times and strength development and compared to the same mix prepared with potable or distilled water.

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