A Review on the selection of the variant Water in Concreting

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Abstract. According to the global agencies of world health organization, world metrological organization and UNICEF, the utilization of fresh water goes on enlarging from twenty century due to overpopulation and frequent implementation of safe accessible water in relative fields, diminishing the quantity and quality available which ultimately causes gap between ecology and environment for livable water. In our construction industry, this safe water can be saved to a large extent by just interchanging this water by various water available viz. seawater, waste water, sewage water and waste wash water based on literature data and studies which show normal and insignificant changes in the strength of cement hardened concrete. This literature based study will provide the base for adoption of waste water as a source in the construction field for preparing the formwork and a small donation towards national water saving programs launched by government of India.

Keyword: Seawater, Brackish Water, Waste Water, Fresh Water, Compressive Strength

1. Introduction
In India, population ranges to approx 132 crore on 9 Feb. 2019 by the estimates of United Nations Estimates and contributing towards world population of about 17.75% of the total world populations[1]. Currently in India, safe fresh water is not available for about 75 million[2]–[5] due to their emerging share in domestic and commercial applications[3],[6]. Providing and satisfying the water demand to such huge population is a very difficult job[7]. Increasing population with adverse climatic environment affects the available resources specially fresh drinking water which is not accessible to some parts of world[8]. However fresh potable water can be interchanged by some available non usable water sources for construction purpose[9] because there are limited sources of fresh water hence one should know the opportunity with waste water which can be used for construction purpose[10] in which concrete is a backbone for entire structural framework. Concrete in general is a fusion of coarse aggregate and mortar[11]–[17]while mortar stands for mixture of fine aggregate, water and cement. Internal properties such as long term durability, versatilility, cost of structure and simplification of construction create the concrete as a premier material[18]. In this review paper, different water characteristic, their manner of reaction with cement concrete and the possible impact is studied based on the literatures.
2. Literature Review

This literature based study is commenced with the aid of previous data dealing in this subject matter, covering national, international publications from journals and conferences.

2.1. Some Important Definitions

2.1.1. Seawater

The water as a origin from sea is known as seawater[19] which surround greater than 3/4 of the earth’s lithosphere[20]. It is evident that seawater has salty taste having its salinity of 3.5%, in general greater than fresh distilled drinking water. During and after 1960’s, the temperature increase was recorded as 0.13°C while 0.04 of salinity increase during 1956-1998 in Western Mediterranean Sea[21].

Table 1: Acceptable Limits for Impurities

| Type of Substances          | Limited Percentage Of Solids By Weight Of Water |
|-----------------------------|------------------------------------------------|
| Organic                     | 0.02%                                           |
| Inorganic                   | 0.30%                                           |
| Sulphates as CaCO₃          | 0.04%                                           |
| Alkali Chloride as CaCl₂    |                                                 |
| 1. Plain Concrete           | 0.20%                                           |
| 2. Reinforced Concrete      | 0.05%                                           |

Seawater have drawback also as it alter the engineering properties of cement like permeability and setting time etc. but adoption of different supplementary cementious materials and natural pozzolans is effective in achieving target results[22].

As per study, the seawater has greater compressive strength after a decade showing negligible changes in strength when comparing with standard distilled potable water. However mori-et-al, shows in their study that the changes in compressive strength of both water after one decade have comes to be very small and hence can be neglected in some extent. For such problems, mixing of external agents like pozzolans to the cement paste enhance the efficiency and filling their capillary pores hence increasing compressive strength due to decrease in void spaces in the system[23]. Sea water should be analyzed for injurious and deleterious materials which cause sulphate attacks, corrosion and acid attacks etc. due to unwanted elements within it. The presence of chloride ions in the seawater imposes efflorescence and corrosion as main problems in any structure. This corrosion will continue until the reinforced steel bar gets fully eroded. Steel bar in the concrete as a strength source is the main body of the structure hence selection of seawater should be smartly chosen.

Table 2: Effect of dissolved salts in water on compressive strength

| Percentage Salts | Percentage Decrease in Strength |
|------------------|--------------------------------|
| 0.5% SO₄        | 3.9-4%                         |
| 1% SO₄          | 9%-10%                         |
| 5% NaCl         | 25%-30%                        |
| CO₂             | 15%-20%                        |

According to the Neville (2001) seawater shall be avoided for concreting reinforced by the steel bar due to the possibility of corrosion[24]. However the effect cannot be seen after 10-20 years and decreased with increasing ages[8], [25].
Table 3: Ions present in the seawater as salts

| Salts     | Percentages |
|-----------|-------------|
| Chloride  | 51.3%       |
| Sulphates | 7.2%        |
| Sodium    | 28.5%       |
| Magnesium | 3.6%        |
| Calcium   | 1.3%        |
| Potassium | 1%          |

To overcome the problems, one should understand the behavior of such water with the different aspects. These may be type of cement used, use of pozzolans and admixtures, high water to cement ratio, porosity during and after casting & curing, heat of hydration, etc. As these factors are primarily the main sources hence analyzing these factors are utmost important. A wide adoption of proper cement type and pozzolans like alumina cement and blast furnace slag (BFS) can lead to the betterment from ordinary Portland cement (OPC), moderate heat Portland pozzolans cement (MHPC) and high early strength pozzolanic cement[8]. Law water to cement ratio such as .26 or proper doses of admixtures like BFS, fly ash etc.[26], investigated as a perfect medium to cater steel corrosion in existing reinforced concrete structure.

Table 4: pH requirement as per different codes for water

| Item | Code      | Range | Statements |
|------|-----------|-------|------------|
| pH   | IS 456-2000[27] | ≥6.0 | Water used should be excluded of undesirable factors which harm the objects during curing and mixing like salts, organic substances etc. |
| pH   | AS 1389[28]   | >5.0 | Water used from RMC plants can be used for mixing purpose but it should be stored firstly as per clause 3.2.3 with the permissible ranges and quality Procedure is as per AS/NZS 158.505.1 |
| pH   | ACI 318 M-08[29] |   | All natural portable water with no taste and odor can be used for mixing for concreting. |
| pH   | EN 1008[30]   | ≥4.0 | Waste water should comply with clause 4.2,4.3.1,4.3.2,4.3.3 and chemical specifications as per 4.3.4 |

2.1.2. Corrosion and Anti-Corrosion Material in Seawater

Corrosion in reinforcement bar primarily depends on the presence of oxygen. In seawater, amount of dissolved oxygen is quite less however corrosion rate is faster in tidal zones where dissolved oxygen can be found in greater amount hence the steel bars corrode in seawater in submerged conditions[31]. Iron oxide interacts with the chloride to form compounds which causes rusting of steel bar. These chloride (Cl⁻) ions progressive to strike the reinforced bar till the oxide layer is destroyed[32]–[34] However corrosion inhibitors like calcium nitrate, sodium nitrate, amines, ester amines, di-methyl ethanolamine, phosphates and sodium benzoate reduces the risk of corrosion and works as a primary corrosion reducers. Also concrete with alumina content or BFS cement imposes a severe impact on steel corrosion. In addition, use of 2% NaNO₃ a corrosion inhibitor also shows a positive impact on reducing the corrosion. The addition of calcium nitrate accelerates the early age
strength, reducing the later age strength & increasing cement hydration[35].

2.1.3. Setting Time with Seawater

For fresh water, the normal setting time lies within 30 min.-600 min. which is a usual range[27] however the setting time of seawater mixed with cement greatly influenced the setting time. Seawater when used in mixing during and after construction reduces the setting time upto68% which is much larger hence suitable doses of retarders or admixtures like soluble carbohydrates viz. sugar, water soluble carbohydrates like starch, dextrin, borax, tartaric acids, and salts should be incorporated[36]. Also inorganic retarders such as hydroxides of zinc and lead, alkali, bi-carbohydrates, calcium borate can be used to delaying the setting time of cement and offsetting the temperature and seasonal variations.

2.1.4. Brackish and waste water

Waste water are the varieties of water coming from many sources including human activities such as water from toilet fixtures, water from dish washer, food preparatory sink, bath tubs, sinks and drains, laundries, spas, and sometimes from vehicle cleaning stations etc. This water basically goes to the drains as waste sources. In India lots of waste water produces every year hence this water can be effectively applied to the construction field and can be properly adjusted to cut down the dependencies to fresh water over the period of time.

According to the Italian law [L.10/05/76 N.319], sewer cannot be directly feed by these water because of objectionable suspended matter and consequent pH ranges of greater than 9.5. however water is firstly collected in the storage for treatment and there after treated and clean water is reused in the production of concrete blocks but the level of sediments should be adjusted before applying in into mixing[37] which ultimately producing safe, clean environment and giving cheap procedure for testing and manufacturing because of widely available of waste water.

In recent trades, special attention were given to this platform for applicability of reuse water from industrial, domestic and commercial excreta for making concrete and showing no adverse effect on the fresh and stone formed structure and hence the compressive strength[38]–[44] because the ultimate compressive strength of concrete with these substances should not be lesser of 90% of the cubes from fresh distilled water[27], [45].

Table 5: Standard specifications for chemical properties49,50

| S. No. | Water Quality Parameter | Permissible Limits | Unit |
|-------|-------------------------|--------------------|------|
| 1.    | Appearance              | Colorless          | -    |
| 2.    | Odor                    | None               | -    |
| 3.    | Turbidity               | No Turbid          | -    |
| 4.    | pH                      | 6.5-8.5            | -    |
| 5.    | Alkalinity              | 600                | mg/l |
| 6.    | Hardness                | 600                | mg/l |
| 7.    | Chlorides               | 1000               | mg/l |
| 8.    | Total Dissolved Solids(TDS) | 2000            | mg/l |

Table 6: chemical and physical properties with permissible ranges

| S. No. | Content | Permissible Limits | References |
|-------|---------|--------------------|------------|
| 1.    | pH      | 3                  | [31], [46] |
|       |         | >5                 | [28]       |
|       |         | 6                  | [27]       |
2. **Total Solids**

| Range       | Value |
|-------------|-------|
| 50,000      | [49]  |
| 5000-10000  | [50]  |
| 4000        | [51]  |

3. **Suspended Solids**

| Value | [27], [50] |
|-------|-------------|

4. **Dissolved Solids**

| Value | [27] |
|-------|------|

5. **Organic Solids**

| Value | [27] |
|-------|------|

6. **Inorganic Solids**

| Value | [27] |
|-------|------|

7. **Alkalinity as CaCO₃**

| Value | [47][28] |
|-------|----------|

8. **Sodium carbonate & Bi-carbonate**

| Value | [54] |
|-------|------|

9. **Carbonate**

| Value | [27], [55] |
|-------|-------------|

10. **Bi-carbonate**

| Value | [27] |
|-------|------|

11. **Chloride for plain concrete**

| Value | [27], [40] |
|-------|-------------|

12. **Chloride for reinforced concrete**

| Value | [27], [40] |
|-------|-------------|

Brackish water, the water resulting from mixing of sea water and fresh water together. The brackish water has high salinity when compared to seawater as 0.5-2 ppt. (parts per thousands). Brackish water originated in the sense of oil production and from fossil aquifer. Water from oil production forms the huge waste in the process of oil exploration and produced around more than 10 times the capacity of water during oil exploration[57]. However waste water and brackish water should be checked for BOD, COD, their alkalinity, hardness, pH, suspended solids, salts content and sometimes turbidity before application in the mixing of concrete.

In all the replacement of water samples with fresh water, this water can be corporate during the mixing and curing and hence the compressive strength is checked.

| Test | Code        | Range                  | Statement                                                                 |
|------|-------------|------------------------|---------------------------------------------------------------------------|
| Compressive strength | IS 456-2000[27] | Should not be less than 85% of average compressive strength of standard specimen. | Strength shall be taken as average of three specimens with variations less than ±15% of mean, otherwise test results failed. |
|      | AS 1379[28] | Should not be less than 90% of average strength of standard sample made up of drinking water source. | Strength will be taken at 7 days and 28 days made up of drinking water as per AS1012.9 |
|      | ASTM C94[49] | Should not be less than 90% of average strength of standard sample made up of distilled water. | Taken as 7 days strength of cement mortar or concrete. |
|      | EN 1008[30] | Should not be less than 90% of average strength of standard sample made up of distilled water. | Strength will be taken at 7 days and 28 days made up of waste wash water. |
Hence the compressive strength will be as per the available codes specifications which govern the criteria for adoption of suitable water. It should be noted that the compressive strength of the specification can be enhanced by adding the external agents such as pozzolans and supplementary cementious materials. Hence desired strength can be achieved even in the abnormal condition hence giving a pathway for suitability of waste water in mixing of concrete preparations.

3. Conclusion

It is well known that different water has different physical and chemical properties. These physical and chemical properties may be useful in some cases while in some cases, it degrade the structural components specially in high rise structure whose safety and sustainability totally depends on quality and better supervisions. The impurities present in the water causes early strength and early setting of cement because water have different solid substances and salts which not only sets the cement but also reduces the voids hence increasing the compressive strength. The application of proper water depend upon numerous factors such as construction field location, their surroundings, dry or wet area in between, and availability of these resources etc. hence proper justifications for adaptability of these reusable water shall be analyzed before using it. Following conclusions are scaled based on the literature

1. The use of reusable water can lead to the increase in the compactness due to decrease in the workability of concrete because of addition of fine grades from the sources and decreased water content. Hence lesser voids are desirable from the early strength and less prone to freezing- thawing actions & also lesser prone to sulphate and acid attacks. Hence greater durability can be achieved.

2. From literature it can be concluded that the compressive strength of concrete coming up from variant water is greater than 90% as that of concrete made up of fresh distilled water. Hence the remaining strength can be avoided when considering the environmental and global problems & scarcity of water. The adaptability of this water not only reuse water available but also decreasing potential demand for fresh water.

3. Water leading to the corrosion is undesirable from strength point of view. It is observed that greater the pH range, lesser the degree of corrosion. Also it can be derived that pH value of water below 3.0 causes more corrosion.

4. Sea water specially causes corrosion but the effect of corrosion is less after 10-20 years but proper admixtures or SCM’S reduces the corrosion effect significantly.

5. Waste water with greater BOD, COD, TSS and TDS is undesirable from strength point of view. However such water with acceptable limits can be used in the field.

6. Lower pH in water causes lesser compressive and tensile strength of concrete made up of variant water as compared to concrete made with fresh water.

7. Poor control and supervision during concreting operation when using these water also compromising on strengths.

8. Recycled and reusable water leads to decrease in capillary water absorption of concrete and porosity of concrete hence improved durability due to fillers in the form of impurities from such water is achieved.

Hence such water should be properly justified in contrast to fresh water when dealing in the ground; practically it is seems to be better to use in reducing the environmental problems and maintaining balance.
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