Effect of Natural Organic Materials as Admixture on Properties of Concrete

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Abstract

Objectives: To study the influence of natural organic materials (i.e. gram-flour, ghee and triphala) as admixture on the durability of concrete. A new method was proposed with 70% loading of average compressive strength to know the durability of concrete under practical conditions. Methods/Statistical Analysis: Use of chemical admixtures in concrete is a common practice in modern construction. Although chemical admixtures improve properties of concrete but also create leaching problem. The paper presents, the various experiments performed to identify the influence of natural organic materials as admixture on durability of concrete. Electrical resistivity, ultrasonic pulse velocity (UPV) and carbonation tests were performed on hardened concrete for 0.4 and 0.45 w/c ratios. Findings: Based on the above results it was found that addition of gram flour provided better durability in terms of electrical resistivity, UPV and carbonation for both the w/c ratios over normal concrete. Even under 70% loading, better durability results were noticed for concrete with gram flour. Although for concrete with ghee and triphala poor results were noticed. Most of the previous work were performed on cement and lime mortar. The present work is performed on the concrete with use of advanced equipment. Application/Improvements: Utilisation of waste food grain causing environmental problems in concrete as admixture in place of chemical admixtures. Research shall discourage use of chemical admixtures in concrete as they are responsible for environmental pollution.

Keywords: Carbonation, Electrical Resistivity, Proposed Durability Method, UPV

1. Introduction

Usage of chemical admixtures in concrete is a common practice in modern construction. Use of chemical admixtures in concrete reduce water demand and improve properties of concrete. Although use of chemical admixtures provides better concrete properties but also responsible for environmental pollution. Impact of chemical admixture on environmental can occur when chemical admixtures are expose to environment or when dumping concrete granulate containing admixtures after demolition of structure or when concrete granulate is used as gravel replacement in construction (Figure 1), as the concrete admixtures are very readily soluble in water, hence create environmental problem due to leaching. So it is desired to find alternative admixtures that provide better concrete properties, also don't produce adverse effect on environment. In the ancient period various natural organic materials were used with concrete and mortar. Organic admixtures (herbs) are locally available plants and animal derivative and the major content in these materials are proteins. The organic materials like black gram, potato starch, egg white, cactus gluey liquid etc. These organic materials improve workability, compressive strength, tensile strength, plasticity etc.

Due to deprive transportation services, lack of storage space and lack of maintenance, wastage of food grains is high in India. According to United Nations Development program (UNDP) almost 40% of the total food production is wasted in India due to Poor transportation facilities.
and lack of storage space. The total cost of food wasted in India is Rs 58,000 cores per year\(^2\). According to The Food Corporation of India (FCI), as much as 1, 94,502 MT of food grain worth cores of rupees was wasted in India due to various reasons between\(^2\)\(^5\).

So these waste food grains can be utilizing as natural organic admixture in concrete.

Figure 1. Life-cycle of chemical admixtures\(^9\).

Several investigations were performed with the natural organic materials in the past. Some of them are mentioned below:

The properties of mortar on fresh state were checked with potato starch. Properties like consistency, density, air content, water retention capacity and setting time were determined to know the influence of potato starch on the properties of aerial lime-based mortars. Depending on dosages it acts like thickener and plasticizer\(^2\)\(^6\).

The usage of cactus extract provided better properties in cement mortar. It develops better plasticity and water absorption characteristics of cement mortar\(^2\)\(^7\).

The use of sticky rice in mortar provided better microstructure properties. It was observed that the sticky rice worked like a matrix of bio-mineralization which improved the microstructure of the calcium carbonate crystal. The compatibility of sticky rice and calcite formed during the hardening of the sticky rice mortar, which may be the probable cause of excellent performance of the mortar\(^2\)\(^8\).

The various properties of fresh mortar utilizing super plasticizers with four latexes of the vinyl polymer group and SBR latex in different dosages with respect to setting time, consistency, subjective workability, bleeding, air content and water reduction capacity\(^2\)\(^9\).

The gypsum or baked lime, sand and ash were used in mortar in Indo – Muslim Architecture, Jharoka\(^10\).

The black gram was utilized in mortar, light weight aggregate concrete and normal concrete in earlier period in India. Black gram acted like air entraining agent and also enhanced the adhesive and hydrophobic properties of cement mortar and concrete. Adding of oil along with black gram acted like a defoaming agent and enhanced the hydrophobicity of lime mortar and concrete\(^2\)\(^11\).

Various natural polymers had been used in construction. Natural proteins and polymers like polished gelatinous rice paste, pluses, molasses, boiled stems and leaves of banana plants, oils, egg whites cashew nut shell, liquid resin, gluey fluid from cactus plants and natural rubber latex were used\(^12\).

The review of past literature suggested that the use of natural organic materials provided better properties of concrete without affecting environment.

2. Methodology / Experimental

2.1 Materials

43 grade Ordinary Portland cement (OPC) was used for preparation of concrete as per BIS 4031:1988.

Natural sand passing from 10mm sieve was used as a fine aggregate. It was tested as per BIS 383:1970Sand was conforming to Zone II. Grading curve for sand is shown in Figure 2. Coarse aggregate passing from 20mm sieve was used for preparation of concrete mix. Sieve analysis was performed to know the physical property of coarse aggregate. To achieve the final grading of coarse aggregate as per 383:1970\(^14\), 20mm and 10mm aggregate were combined 60% and 40%. Grading curve for 20mm, 10mm and 20mm and 10mm combined are given in Figure 3,4 and 5 respectively. Combined coarse aggregate and fine aggregate were mixed in 60:40. The combined grading is shown in Figure 6.

Natural organic materials were used as admixture in concrete.
2.2 Mix Proportions
Concrete mix (control mix) was designed as per Indian standard concrete mix design method (IS 10262:2009) and its comparative performance was verified with concrete mixed with natural organic materials. For the design mix two alternative cases were studied. First was a control mix as per BIS code method. In second case for the same design mix natural organic admixtures were added in concrete. Three different natural organic materials were added in concrete and two w/c ratio 0.4 and 0.45 was considered. Designation and percentage organic materials are shown in Table 1.
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Table 1. Quantity of additives used

| Cube No. | W/C Ratio | Designation | Quantity of additives (%) by weight of cement |
|----------|-----------|-------------|-----------------------------------------------|
| 1        | 0.45      | Normal concrete | -------- |
| 2        | 0.45      | Ghee         | 0.5    |
| 3        | 0.45      | Gram flour   | 1      |
| 4        | 0.45      | Triphala     | 0.5    |
| 5        | 0.4       | Normal concrete | -------- |
| 6        | 0.4       | Ghee         | 0.5    |
| 7        | 0.4       | Gram flour   | 1      |
| 8        | 0.4       | Triphala     | 0.5    |

2.3 Preparation, Casting and Testing of Specimens

For each case twelve, 100 mm cubes were cast. In all 96 cubes were cast. All the cubes were vibrated on vibration Table 2 to get proper compaction. After casting, all the test specimens were finished with a trowel. After 24 hours, cubes were de-molded and were put into water for curing. 9 cubes were cast for each case for 0.45 w/c ratio and 12 cubes were cast for each case for 0.40 w/c ratio.

2.4 Concrete Properties

Electrical resistivity, UPV (IS 13311:1992) and carbonation depth were determined on hardened concrete to know the durability of concrete with various organic materials and compared with normal concrete.

2.5 Proposed Durability Test

The micro cracks are formed in concrete due to shrinkage and thermal changes. Under the loading these micro cracks open up and allow the harmful substance to penetrate, which reduce the serviceability of structure. Since concrete is generally the exterior component, it is subjected to various physical and chemical attacks. Generally, these attacks are cyclic in nature. The present durability test was developed by simulating the above conditions.

In the proposed durability test, 70% load of 28 day’s average compressive strength was applied on 3 cubes and then kept for alternate wetting and drying cycle for 60 days. After 60 days of wetting and drying cycle cubes were tested for electrical resistivity and UPV. Then cubes were kept in carbonation chamber for 30 days. After 30 days, compressive strength and carbonation depth were determined.

3. Results and Discussion

Electrical resistivity, UPV and carbonation were determined for hardened concrete to understand durability. These experiments were performed for without loading and with 70% loading condition.

The result of electrical resistivity without loading condition is shown in Figure 7. For without loading condition, increase in electrical resistivity was observed for ghee and gram-flour for both the w/c ratios. The value of electrical resistivity enhanced by 6.20% and 8.86% over control concrete for 0.45 and 0.4 w/c respectively. Addition of gram flour had shown better electrical resistivity for both the w/c ratio mixes. Electrical resistivity was improved by 23% and 26.65% over control concrete for 0.45 and 0.4 w/c respectively. The probable cause of increase in electrical resistivity could be the better packing due to finer particle size of gram flour, which results reduced voids in concrete mix.

Table 2. Quantities of various materials used for compacted concrete

| Cube No. | W/C Ratio | Designation | Quantity of cement (kg) | Quantity of aggregate (kg) | Quantity of additives (gm) |
|----------|-----------|-------------|-------------------------|-----------------------------|----------------------------|
| 1        | 0.45      | NC-I        | 4.8                     | 13.1                        | 7.7                        | ------ |
| 2        | 0.45      | CG-I        | 4.3                     | 13.7                        | 8.1                        | 21.5 |
| 3        | 0.45      | CGF-I       | 4.3                     | 13.7                        | 8.1                        | 43   |
| 4        | 0.45      | CT-I        | 4.3                     | 13.7                        | 8.1                        | 21.5 |
| 5        | 0.4       | NC-II       | 6.8                     | 17.5                        | 9.9                        | ------ |
| 6        | 0.4       | CG-II       | 6.5                     | 18.1                        | 10.2                       | 32.5 |
| 7        | 0.4       | CGF-II      | 6.5                     | 18.1                        | 10.2                       | 65   |
| 8        | 0.4       | CT-II       | 6.5                     | 18.1                        | 10.2                       | 32.5 |
Decrease in electrical resistivity was noticed for concrete with triphala for both the w/c ratios. Decrease in electrical resistivity may be due to hindrance of triphala in hydration process, which results in lesser formation of hydration product and hence results in more porosity.

Figure 8 has shown the relationship between different concrete mix and electrical resistivity with loading condition.

For with loading condition, increase in electrical resistivity was observed for ghee and gram flour for both the ratios. Increase in electrical resistivity was observed by 8% and 13% over control concrete for 0.45 and 0.4 w/c respectively.

Electrical resistivity was enhanced for concrete with gram flour for both the w/c ratios. The value of electrical resistivity was improved by 25.2% and 32.01% over control concrete for 0.45 and 0.4 w/c respectively.

Electrical resistivity was enhanced for concrete with gram flour for both the w/c ratios. The value of electrical resistivity was improved by 25.2% and 32.01% over control concrete for 0.45 and 0.4 w/c respectively.

Addition of triphala provided lesser electrical resistivity for both the w/c ratios. Decrease in electrical resistivity may be owing to hindrance of triphala in hydration process, which results in less creation of hydration product and hence results in more porosity.

The value of electrical resistivity was improved for concrete mixed with ghee, for without loading condition but the value decreased with loading condition, over control concrete. Electrical resistivity value increased for concrete with gram flour for without loading condition and with loading condition for both w/c ratios. The reason of improve in electrical resistivity even under 70% load condition, may be less development of crack, due to finer particle size of gram flour than cement, which provide better packing. Electrical resistivity reduced for concrete with triphala, without loading and with loading condition for both w/c ratios. The reason of reduce in electrical resistivity may be less creation of hydration product which results in more porosity which further responsible for more crack development under loading, as compare to control concrete.

Figure 9 has shown variation of UPV with different concrete mix without loading condition.

For without loading condition, addition of gram flour provided better UPV for both the w/c ratios. Improve in UPV was 0.36% and 0.80% over control concrete for 0.45 and 0.40 w/c ratio respectively. The reason of increase in UPV may be improved packing due to finer size of gram flour than cement which provides less porosity.

Addition of ghee provided lesser UPV for both the w/c ratios. The reason of decrease in UPV may be the poor formation of bond between cement and aggregate which results in more porosity. Addition of triphala provided lesser UPV for both the w/c ratios. Decrease in UPV may be may be owing to hindrance of triphala in hydration process, which shall be verified for validation.
Figure 10 has shown variation of UPV with different materials with loading condition. For with loading condition, increase in UPV was observed for gram-flour for both the ratios. Increase in UPV was observed by 2.1% and 2.75% over control concrete for CGF-I and CGF-II respectively. UPV increased even after applying 70% load of average 28 day’s compressive strength over control concrete. The reason of improve in UPV may be less creation of cracks, due to finer particle size of gram flour than cement, which provide better packing.

Decrease in UPV was noticed for concrete with ghee for both the w/c ratios. The reason of decrease in UPV may be the poor formation of bond between cement and aggregate which results in more porosity which further responsible for more crack formation under load. Drop in UPV was noticed for concrete with triphala for both the w/c ratios. Decrease in UPV may be owing to hindrance of triphala in hydration process, results in more porosity which further responsible for more creation of crack under load.

Figure 11 has shown variation of carbonation depth with different materials for without loading condition.

For without loading condition, drop in carbonation depth was noticed for gram flour for both the ratios. Carbonation depth decreased by 2.41% and 4.84% for 0.45 and 0.40 w/c ratio respectively. The reason of drop in carbonation depth may be improved packing due to finer size of gram flour than cement which provides less porosity.

Addition of ghee in concrete provided higher carbonation depth both the w/c ratios. The reason of increase in carbonation depth may be the poor formation of bond between cement and aggregate which provide more porosity.

Figure 12 has shown variation of carbonation depth with different materials for with loading condition.

For with loading condition, decrease in carbonation depth was observed for gram-flour for both the ratios. Carbonation depth decreased by 6.1% and 11.63% for CGF-I and CGF-II respectively. Carbonation depth decreased even after applying 70% load of average 28 day’s compressive strength over control concrete. The reason of drop in carbonation depth may be less creation of cracks, due to finer particle size of gram flour than cement, which provide better packing.

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of bond between cement and aggregate which results in more porosity which further responsible for more crack formation under load. Addition of triphala in concrete provided higher carbonation depth both the w/c ratios. Increase in carbonation depth may be owing to hindrance of triphala in hydration process, results in more porosity which further responsible for more creation of crack under load.

Higher carbonation depth was noticed for concrete mixed ghee, for without and with loading condition, over control concrete. The reason of higher carbonation depth may be the poor formation of bond between cement and aggregate, results in more porosity which further responsible for more crack creation under load.

![Figure 12. Relation between various materials and carbonation depth with loading (mm).](image)

Drop in carbonation depth was noticed for concrete with gram flour for without and with loading condition for both w/c ratios. The reason of drop in carbonation depth may be less creation of cracks, due to finer particle size of gram flour than cement, which provide better packing. Drop in carbonation depth was noticed for concrete with triphala for without and with loading condition for both w/c ratios. Increase in carbonation depth may be owing to hindrance of triphala in hydration process, results in more porosity which further responsible for more creation of crack under load.

4. Conclusion

The present investigation was taken up with a view to utilize natural organic materials (i.e. ghee, gram flour and triphala) as admixture in concrete. The concept of using organic materials is to eliminate the possibility of environmental pollution due to chemical admixture and to utilize waste food grain as the wastage of food grain in India is high. To know the effect of natural organic additives on the durability of concrete, electrical resistivity, UPV and carbonation tests were performed and compared with control concrete. Based on the results following conclusions are drawn:

4.1 Gram Flour

- Addition of gram flour provided better durability. Electrical resistivity increased for both w/c ratios up-to 26.65%. Even after applying 70% loading, electrical resistivity was more than control concrete. Up-to 31.98% increase in electrical resistivity was observed over control concrete. After applying 70% loading, percentage drop in electrical resistivity was lesser than control concrete.
- UPV increased for both w/c ratios up-to 0.8%. Even after applying 70% loading, UPV was more than control concrete. Up-to 2.75% increase in UPV was observed over control concrete. After applying 70% loading, percentage drop in UPV was lesser than control concrete.
- Carbonation depth decreased for both w/c ratios up-to 4.84%. Even after applying 70% loading carbonation depth was lesser than control concrete. Up-to 11.63% decrease in carbonation depth was observed over control concrete. After applying 70% loading, percentage drop in carbonation depth was more than control concrete.

Since addition of gram flour improve properties of concrete hence gram flour can be recommended to use in concrete as natural organic admixture.

4.2 Triphala

- Drop in electrical resistivity and UPV were noticed for both the w/c ratios.
- Higher carbonation depth was observed for both the w/c ratios.

Since poor results were noticed for concrete with triphala, hence further study is recommended.

4.3 Ghee

- Improve in electrical resistivity was noticed for concrete with ghee. Maximum up-to 8.86% improve in electrical resistivity was noticed. Even after applying 70% loading, electrical resistivity was higher than control concrete. Up-to 12.92% improve in electrical
Generally micro cracks develop in concrete due to shrinkage and thermal stresses. Under the load (i.e. DL and LL) these micro cracks open up and allow water and gases to penetrate which are harmful for concrete steel reinforcement. So the concept of applying 70% loading and cyclic wetting and drying curing is to determine the serviceability by simulating the field condition. 70% loading method may be able to predict service life of structure and also may be used for durability test for concrete under practical condition.

- Under the 70% loading of average 28 day’s compressive strength, drop in electrical resistivity and UPV was observed for the control concrete for both the w/c ratio and the similar trend were observed for concrete mixed ghee, gram flour and triphala.
- Under the 70% loading of 28 day’s compressive strength, increase in carbonation depth was observed for the control concrete for both the w/c ratio and the similar trend was observed for concrete mixed with ghee, gram flour and triphala.

Based on the above results it could be concluded that the 70% loading method results are in similar trend as normal durability method but results may be closer to the practical condition. In the view of that 70% loading method could be suggested.

### 5. Future Scope

In the present work fresh organic materials were used in the concrete. Work should be done with the waste organic materials. The micro structural properties of concrete with theses organic materials should be done. The different percentage of these organic materials should be used to determine the optimum dosage with different w/c ratios before their application in field. In the present study 70% load were applied on the cubes to simulate the field condition. More study should be done with different loading percentage.

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