Improving Durability of Concrete using PVC Waste Flex Banner

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***Abstract* – Durability of cement concrete plays a very important role in performance and life expectancy of RCC Structures. Ingress of water and harmful gases present in atmosphere causes deterioration of concrete and reinforcement steel leading to failure of the structure much before its designed life expectancy. Researchers have tried many materials and methods to increase the durability of the concrete. In this research study waste/used Poly Vinyl Chloride (PVC) flex banner is used to increase the durability of the concrete. PVC flex banner is used in this research as it is not only a plastic waste available in abundance but also it is having many desirable properties like flexibility, water resistance, high strength in itself due to polyester yarn fabric inside it, high abrasion resistance, long life etc. There are number of tests carried out in construction industry to find out the durability of the concrete. Water absorption test is one of the most direct measure of durability of concrete as durability is inversely proportionate to water absorption. In this work water absorption test is carried out on concrete cubes to find out usefulness of waste flex banners in reducing water absorption. Flexure tests on concrete beam wrapped with flex banner is also carried out to observe behaviour of wrapped beam during failure. It is found that the waste PVC flex banner can be effectively used in increasing the durability of concrete by reducing the water absorption. The same can be used in concrete structures with certain precautions so that warning signs during failure are visible.**

***Index Terms* – Waste PVC Flex Banner, Solid Waste Management, Water absorption Test, Durability of Concrete, Flexure Test on concrete.**

1. INTRODUCTION

Cement concrete is one of the most widely used construction material world over. Rapid growth in Infrastructure and Real Estate has put cement concrete at the top of all construction materials. Strength and durability remain the two most important criteria in design, construction and maintenance of concrete structures. While high strength concrete is now more easily available for construction of general civil engineering structures, durability still remains a cause of concern specially in adverse weather conditions like that in coastal regions.

Durability of concrete can be defined as its ability to protect itself against deterioration. It depends manly upon concrete mix proportions (specially water cement ratio), concrete strength and degree of environmental exposure. Some of the other factors which affects the durability of concrete are Cement content, Aggregate-Water quality, water absorption, permeability, curing period, various atmospheric actions, carbonation, freezing, chemical reactions, weathering actions etc. Concrete structures can be durable if concrete paste is in proper ratio, concrete is dense, it has low permeability and water absorption, good quality and well graded aggregate are used, cement and other ingredients are free from chemical impurities, and workmanship is good i.e. mixing, placing, curing and compaction are properly done.

Several researchers have carried out extensive research in increasing durability of concrete by adding or replacing certain ingredients in the concrete with success to varying extent. These techniques cannot be used in existing structures. Many researchers have worked on wrapping of FRP sheets around concrete members in increasing strength and durability of concrete. These techniques are quite costly.

In this research work waste PVC flex banners are used for increasing the durability of the concrete. Flex banners are commonly used for flex printing, hoardings, banners for advertising purpose by almost all commercial and political organisations. PVC flex banners have several unique qualities which makes it a suitable for use in construction industry like it is flexible so it can be easily wrapped around the concrete members, it is long lasting, it can safeguard concrete structures from ingress of water and harmful gases thus making them more durable. Last but not the least it is cost effective material as it is a waste material and otherwise also it is a cheap material.

In this research work Water Absorption Test is carried out on the concrete cubes with and without flex banner wrapping. Flexure test on concrete beam wrapped with flex banner is also carried out to see the behaviour flex wrapped beam during failure.

2. LITERATURE REVIEW

Many researches have been conducted in past to increase durability of concrete by adding or replacing certain ingredient in concrete. Some of these are as follows;

Shanmugavadiv et.al [1] conducted an experimental research in which they replaced natural sand or fine aggregate with manufactured sand. They showed with the help of permeability test that permeability reduced with increasing percentage of manufactured sand in place of natural sand. They conducted rapid chloride penetration test also and found that manufactured sand reduced chloride ion penetrability in concrete as compared to when natural sand was used. They suggested that concrete which is blended with 70% manufactured sand and 30% natural sand gives better results.

Amudhavalli and Mathew [2] conducted an experimental research in which they studied partial replacement of the cement with silica fume and its effect on strength and durability of concrete. They considered partial replacement of the cement with silica fume by 0%, 5%, 10%, 15% and 20% in M35 grade concrete. They performed experimental study on durability and strength of concrete under acid attacks, under which they studied weight loss of concrete in comparison to the normal concrete, compressive strength, flexure strength and split tensile strength after 7 and 28 days of curing. Final test results demonstrated that replacement of cement partially with silica fume improved strength and durability too.

Mageswari and Vadevelli [3] performed an experimental study in which they partially replaced natural sand (fine aggregate) with sheet glass powder. They considered replacement of fine aggregate in proportions of 10%, 20%, 30%, 40% and 50% in different samples. On these samples they performed split tensile test, water absorption test and compressive strength test. They found that as percentage of sheet glass powder increased in concrete, strength also increased up to 20% replacement. They observed that natural sand can be only be replaced up to a maximum of 20% by sheet glass powder. Water absorption in concrete got reduced, workability, compression strength and tensile strength got increased as percentage of glass powder increased up to 20%.

Bubshait et. al. [4] done an experimental study in which they optimally replaced cement by micro silica fume in the concrete. The optimum replacement of cement by silica fume gave high durability, less permeability and give high compressive strength. It can also improve thermal cracking which always occur due to heat of cement hydration. By their experimental study they also found that it also improved durability and make concrete more durable against sulphate and acidic water. These all qualities of silica fume improve performance of concrete.

Malik et.al [5] conducted an experimental study in which they replaced the fine aggregate with waste glass powder. When they replaced 20% of natural sand with waste glass powder there was 15% increase in compressive strength after 7 days, while after 28 days there was a increase of 20% in compressive strength was found. They reported that maximum 30% natural sand can be replaced with waste glass powder. They also reported that by this replacement of natural sand by waste glass powder water absorption reduced and workability increased.

Many researchers have studied the effect of wrapping of FRP sheets around concrete members on strength and durability of concrete. Some of the works are as follows:

Li. Ren et. al [6] carried out an experimental research in which they put their sample of concrete in water which was laminated by carbon fiber reinforced polymer (CFRP) and glass fiber reinforced polymer (GFRP) separately for 30 days for water absorption test. Their test results indicate that CFRP specimens subjected to aggressive environments exhibited good durability without significant degradation in modulus and tensile strength. Whereas, GFRP specimens showed slight decrease in mechanical properties on aggressive environments exposure.

Li et. al [7] they carried out an experimental test on both CFRP and GFRP sheets. They carried out static tensile test on both sheets. They put both CFRP and GFRP sheets under alkali solution at 30, 40,50,60 degree respectively. Their results showed that with increase in time, both CFRP and GFRP sheet's tensile strength and elastic modulus decreases gradually. Based on their results, they developed a modified Arrhenius analysis to predict the long term durability performance of FRP.

Zhang et.al [8] conducted study on mechanical properties and durability of Fiber-reinforced Concrete and demonstrate that the elastic modulus, compressive strength, and anti-carbonization capacity of the fiber-reinforced concrete increase initially and then decrease with increase in fiber content and are better than those of ordinary concrete.

Adding some kind of ingredients to concrete is possible only at the time of making fresh concrete. Therefore, these techniques cannot be applied for existing structures. On the other hand, wrapping of some kind of FRP sheet is a costly affair. In both the cases improvement of durability is found to be marginal at the most with not much success at the level of practical commercial applications. Present work envisages wrapping of waste flex banner as a cheaper and more effective method for improving the durability by limiting water absorption and ingress of atmospheric gases for existing concrete structures subjected to adverse environmental exposure.

3. MATERIALS AND TEST METHODS

3.1 ***Materials*** **–** Various materials used in the experimental work are described below.

3.1.1 Cement Concrete – Nominal Mix Cement Concrete of grade M20 is prepared using Portland Pozzolana Cement (PPC) conforming to IS: 1489-1 (1991), fine aggregate (sand) conforming to zone -II as per IS 383: 2016 and graded coarse aggregate of nominal size 20 mm conforming to IS 383: 2016 in proportion of 1:1-1/2:3 (1 cement: 1-1/2 fine aggregate: 2 coarse aggregate). According to IS 3025, water for mixing in concrete should be free from harmful salts and chemicals. Accordingly, in this experiment filtered drinking tap water is used. Water cement ratio is kept as 0.5 to achieve proper workability.

3.1.2 Flex Banner – PVC flex banners are made up from Poly Vinyl Chloride sheets laminated over polyester yarn fabric [12]. They are specially designed for printing industry. They are widely being used to provide high quality digital print for outdoor banners, advertisement, hoardings printed by large colour plotters and now they can be easily get printed by digital printers too. They can survive even in harsh environmental conditions like heat, rain, frost etc because of its PVC layers with polyester fabric in its back providing strength. Flex banners come in various shapes, sizes and designs. Special ink is used in printing on flex which do not deteriorate even under heavy rainfall and high temperature. There are 2 types of PVC flexes in use. They are Backlit and Frontlit Flex Banners. PVC flex is available in Indian market from 200 to 440 gsm. It is UV resistant; and it is also resistant to various chemical solvents. In this experiment waste PVC flex banners are used as a wrapping on concrete surface to reduce its water absorption and as a result to increase its durability. It is well known that durability increases as water absorption decreases. Waste flex banners of 200 gsm are used in this work.

Fig. 1. Waste Flex Banner

3.2 Test Methods

3.2.1 Water Absorption Test: In this experimental study water absorption test is conducted as per procedure laid down in IS:1124 - 1974. Waste flex banner is wrapped around concrete cubes to find out how it can reduce water absorption in concrete cubes in comparison to the cubes which are not wrapped by flex banner around them.

Total 6 concrete cubes are taken for the water absorption test. Firstly, all the 6 cubes are dried in oven at the temperature of 110 degree Celsius for 24 hours and after that their dry weights are taken. Three cubes are kept unwrapped and remaining three are wrapped with waste flex banner using rubber based carpet adhesive, air dried for one day and dry weight taken. Thereafter, all the 6 concrete cubes are kept under water in water tank for next 24 hours. After 24 hours all 6 concrete cubes were taken out from water tank, surface dried and their weights are again taken.

Fig. 2. Wrapped and unwrapped concrete cubes

Table 1. Water absorption test on unwrapped concrete cubes

Concrete cube without wrapping of flex	Weight after drying in over at 110 degrees for 24 hours W1	Weight after keeping in water for 24 hours W2	Percentage of Water absorption [(W2-W1)/W1]*100	Average Percentage of water absorption
C1	8.050 kg	8.240 kg	2.36%	2.84%
C2	8.100 kg	8.320 kg	2.72%	
C3	8.110 kg	8.340 kg	2.84%	

Table 2. Water absorption test on wrapped concrete cubes

Concrete cube wrapped with flex	Weight after drying in over at 110 degrees for 24 hours W1	Weight after keeping in water for 24 hour W2	Percentage of Water absorption [(W2-W1)/W1]*100	Average Percentage of water absorption
CF1	8.100 kg	8.160 kg	0.74%	0.70%
CF2	8.120 kg	8.170 kg	0.61%	
CF3	8.110 kg	8.170 kg	0.74%	

3.2.2 Compression Test on Concrete Cubes: Three concrete cubes of standard size (150 x 150 x 150 mm) are tested for compression in a digital compression test machine to ascertain the strength of concrete mix.

Table 3. Compression test on concrete cubes

Description	Cube Specimen 1	Cube Specimen 2	Cube Specimen 3
Load at failure (kN)	645 kN	575 kN	605 kN
Compressive Strength (N/sq.mm)	(645000/22500) = 28.67	(575000/22500) = 25.55	(605000/22500) = 26.89
Average Compressive Strength (N/sq.mm)	(28.67 + 25.55 + 26.89) / 3 = 27.04		

3.2.3 Flexure Test on Concrete Beam: Concrete beam specimens of standard size (150 x 150 x 700 mm) are prepared from the same concrete mix. Waste flex banner is wrapped around these beams using rubber based carpet adhesive and dried in air for two days. The beams are tested for flexure in Universal Testing Machine with single point loading system. The behaviour of the beam and the flex banner is observed at the time of failure of the concrete beams under flexure. It is observed that flex wrapping worked properly without delamination. However, the flex wrapping concealed the visibility of cracks generated in the beam at the time of failure. This appears to be a limitation of using flex banner for flexural members near the zone of cracking.

Fig. 3. Flexure test on concrete beam wrapped with waste flex banner

4.Results and Discussion

The water absorption test conducted on M20 grade concrete cubes with and without wrapping of waste PVC flex banner are reported in Tables 1 and 2 above. These are further compiled in table 4 below for comparison purpose.

Table 4. Comparison of water absorption in concrete cubes with and without wrapping of waste flex banner

Description of Concrete Cube	Average percentage of water absorption	Comparison of Water Absorption
Concrete cubes without wrapping of PVC flex banner	2.84%	[(2.84-0.70)/2.84] x 100 = 75.35 %
Concrete cubes wrapped with PVC flex banner	0.70%	75.35% water absorption reduced due to wrapping of flex

Thus, it is found that by wrapping of waste PVC flex banner, the water absorption of M20 concrete cube reduces by more than 75%. This reduction is quite significant.

However, it is seen from flexure test on concrete beam that the wrapping of flex banner conceals the visibility of occurrence and propagation of cracks in concrete during failure. These cracks act as warning signs before failure. Therefore, care need to be taken while wrapping flex banner around beams to avoid regions where cracks are likely to occur. Either those areas can be left unwrapped or alternatively some kind of transparent flex banners may be wrapped around those areas. Since columns do not pose such problems, flex banners can be wrapped around the whole column.

5.Conclusions

1. It is found that wrapping of waste flex banner significantly reduces the water absorption of concrete. As water absorption is one of the measures of durability of concrete, it can be inferred that durability can be significantly improved by wrapping of flex banner on concrete surface. This can find application in protecting existing concrete members exposed to adverse environment exposure. Exposed concrete members subjected to deterioration due to carbonation and other weathering actions specially in coastal region or in industrial areas can be protected to a great extent and made more durable by wrapping of waste PVC flex banners.

2. Wrapping of flex banner around concrete beams may hinder visibility of warning signs (in the form of cracks) during failure. Therefore, regions where cracks are likely to occur may be kept either unwrapped or wrapped with transparent PVC flex banner. Compression members like concrete columns may be fully wrapped with PVC flex banner.

3. Various advantages of using PVC Flex Banners are as follows;

    a) Easy installation – can be wrapped around concrete structures using normal rubber-based carpet adhesive available in market, without causing delamination under loading.

    b) Provides shield against ingress of water and harmful gases in adverse environmental exposure.

    c) Can be used for indoor and outdoor both. It is time tested for long life.

    d) Cheap and economical – Being a waste material it can be economically used as well as its use contributes in solid waste management. Otherwise also it is a very cheap material as compared to the other available alternatives.

    e) Resists against both fading and weathering actions for many years.

Besides water absorption test there are many more tests which are used to be performed on concrete to test its durability. These tests can also be performed on concrete wrapped with waste flex as a further study. Waste flex of different GSM can be used and tested for comparison. Specially made flex banner with specially designed fibre can be thought of for use in different applications.

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