EFFECT OF SURFACE TREATMENT OF RUBBER ON THE PROPERTIES OF RUBBER BASED CONCRETE

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***Abstract*— This paper presents the effect of surface treatments of tyre rubber on the properties of rubber based concrete. Two types of surface treatments were given to the waste rubber. The rubber chips were treated with sodium hydroxide solution and cement paste to improve the adhesion of rubber aggregates with the concrete matrix. Slump test, Compressive strength, Flexural strength & Split tensile strength tests were performed at time intervals of up to 28 days. The results showed a decrease in the mechanical strength of concrete after the addition of shredded rubber (as partial replacement of coarse aggregates) without treatment as well as a decrease of workability. It was also observed that among two surface treatments the treatment with Sodium hydroxide solution caused an increase in the mechanical strength of the rubber based concrete.**

Keywords—* *Artificial aggregates, hydrophilicity, landfill, light weight concrete, ***.non biodegradable waste, rubbercrete, Scrap tyre rubber, surface treatment of rubber.***

I. INTRODUCTION

As the number of vehicles is increasing day by day, so is the number of scrap rubber tyres. Every year almost 1000 million tyres reach the end of their useful lives. [1] At present large number of tyres are stockpiled or landfilled, about 3000 millions inside EU and 1000 millions in the US. [2] The number of scrap tyres from vehicles will reach to about 1200 million by the year 2030[3]. Most of these scrap rubber tyres are dumped into the landfill sites but being a non biodegradable material, they are posing threat to the environment .If these rubber tyres are kept as such, the rain water can get accumulated inside them, which can result in breeding of mosquitoes and other pests. [1,2,4] Another method of getting rid of these scrap tyres was by burning them ,but this will result in air pollution because many poisonous gases will get added to the atmosphere and the ash left behind after burning of tyres will result in soil pollution & if this ash gest added to the surface runoff it will contaminate water bodies[5].So.in order to save the environment it is the need of the hour to utilize these scrap tyres. This rubber waste can be potentially used in concrete construction sector. By doing this the overall cost of the concrete will go down. The scrap rubber can be used in concrete in many forms. It can be used in chip form or shredded form to replace some amount of coarse aggregates, in crumb form to replace some percentage of fine aggregates and in ground form to replace some percentage of cement. Many experiments have been carried out to study the effect of scrap rubber on the properties of concrete. In some experimental investigations crumb rubber was used to replace some percentage of fine aggregates [6-13].while in others shredded rubber was used to replace some percentage of coarse aggregates [14,15] Many properties of rubber based concrete were studied and were compared with the control. The compressive strength of rubber based concrete specimens was less than that of the control in both the cases but there was a larger reduction of mechanical properties in case where course aggregates were replaced by shredded rubber rather when fine aggregates were replaced by crumb rubber. The rubber based concrete showed lower unit weight as compared to the plain concrete so it can be used as light weight concrete. There was a positive effect on the post –cracking behaviour of rubber based concrete, good energy absorption and ductility behaviour was observed in case of rubber based concrete [16]. From the literature it is clear that the rubber based concrete finds its applications in concrete structures located in earthquake prone areas and at places where high impact loads are acting like railway sleepers.From the literature review it is clear that rubber based concrete has many applications, but there is a need to work on improving the adhesion between rubber and concrete matrix.. This paper presents the effect of Sodium hydroxide (NaOH) treatment and cement paste treatment of waste rubber on the properties of rubber based concrete.

II. EXPERIMENTAL PROGRAM

In this experimental investigation ten different mixtures of concrete were prepared. Among the ten mixes one was control concrete with 0% of rubber content and rest of nine mixes were prepared by replacing some percentage(by weight) of coarse aggregates with shredded tyre rubber. Among the nine rubber based concrete mixes three mixes were prepared with untreated shredded tyre rubber (at percentages of 5%,10% &15%), next three were prepared with NaOH treated rubber chips(at percentages of 5%,10% &15%) and the last three by using cement treated rubber chips (at the percentages of 5%,10% & 15%). At all the percentages rubber aggregates were introduced in the concrete as partial replacement of coarse aggregates by weight. For all the ten mixes cement content, fine aggregate grading and water cement ratio was kept constant. Various tests were conducted on all the mixes in fresh state and hardened state. Slump test was conducted on the concrete in fresh state and compressive strength, flexural strength and split tensile strength tests were conducted on the concrete specimens in hardened state.

A. Material

Ordinary Portland Cement 53 Grade, river sand obtained from local source, confirming IS grading zone III , crushed stone in sizes of 20 mm and 10 mm, tap water, shredded scrap rubber of tyres & NaOH solution were used to carry out this experimental investigation.

A. Mixture Proportioning

In this experimental study the mixture proportion given in Table 1 was used. Hand mixing on a non absorbing platform was carried out to prepare all the concrete mixes.

Table 1. Mix proportion of concrete.

S.no	Mix ID	Cement (kg/m^3)	F.Agg. (kg/m^3)	C.Agg.		%Re-place-ment	w/c
				Gravel(kg/m^3)	Rubber (kg/m^3)		
1	PC	436	654	1309	**0**	**0**	0.45
2	UTR-5	436	654	1243	66	5	0.45
3	UTR-10	436	654	1178	131	10	0.45
4	UTR-15	436	654	1112	196	15	0.45
5	NTR-5	436	654	1243	66	5	0.45
6	NTR-10	436	654	1178	131	10	0.45
7	NTR-15	436	654	1112	196	15	0.45
8	CTR-5	436	654	1243	66	5	0.45
9	CTR-10	436	654	1178	131	10	0.45
10	CTR-15	436	654	1112	196	15	0.45

Where;

PC represents control concrete

UTR -5,UTR-10 & UTR -15 represent concrete having 5%,10% &15% of untreated shredded rubber as partial replacement of course aggregates.

NTR-5, NTR-10 & NTR -15 represent concrete having 5%,10% &15% of NaOH treated shredded rubber as partial replacement of course aggregates

And, CTR-5, CTR-10 & CTR -15 represent concrete having 5%,10% &15% of Cement paste treated shredded rubber as partial replacement of course aggregates.


Figure 1: NaOH treated rubber. Figure 2: Cement paste treatment given to rubber.

Figure 3: Compressive Strength Test on Cube Specimens Figure 4 : Flexural Strength Test

Figure 5: Split Tensile Strength Test

C. *Preparation of samples*:

All samples were prepared in the Concrete Laboratory at IUST. Cube samples of size 150mm, prisms of size 500mmX100mmX100mm and cylinders of size 100mmX200mm were cast for conducting compression strength, flexural strength and split tensile strength tests respectively.

III. RESULTS AND DISCUSSIONS

The results of the tests conducted on fresh concrete and hardened concrete are shown in Table 2 & Table 3.

Table 2: Slump Test results.

Sample	**Slump** (mm)	**Slump loss** (%)
PC	50	0
UTR-5	47	6
UTR-10	45	10
UTR-15	43	14

NTR-5	48	4
NTR-10	44	12
NTR-15	40	20
CTR-5	45	10
CTR-10	42	16
CTR-15	35	30

Table 3: Strength tests on hardened concrete

Sample	**Compressive Strength** (N/mm^2)	**Split Tensile Strength** (N/mm^2)	**Flexural Strength** (N/mm^2)
PC	27.33	2.38	8.1
UTR-5	19.8	2.1	7.95
UTR-10	23.5	1.9	6.9
UTR-15	20.4	1.6	7.4
NTR-5	23.3	3.82	9.3
NTR-10	25.3	5.72	8.75
NTR-15	15.6	6.36	7.51
CTR-5	22.2	4.76	9.25
CTR-10	15.5	4.28	8.51
CTR-15	21.7	4.076	8

From the test results it is clear that there is decrease in the slump of fresh concrete with the increase in the percentage replacement of coarse aggregates by rubber as shown in Figure 6 .

The comparative analysis of slump has been done using percentage slump loss factor.

Where,

Slump loss (%) = $\left(\frac{s_o - s_f}{s_o}\right)100$

s_o = slump in mm of control mix;

s_f = slump in mm of rubber based concrete mix.

With the increase in the percentage replacement of coarse aggregates by rubber there is an increase in the percentage slump loss. At 5% replacement the slump loss is 6% which further increases to 10% and 14 % at 10% &15% replacements respectively.This low workability of rubber based concrete is due to the hinderence in the movement of concrete particles by rubber particles and lack of adhesion between cement paste and rubber particles.By giving surface treatment to the rubber aggregates the slump values at respective percentages have increased.Concrete prepared by using NaOH treated rubber particles have shown greater slump values than that prepared by using cement paste treated rubber aggregates.This shows that NaOH treatment has increased the mobility of rubber aggregates than the cement paste treatment.

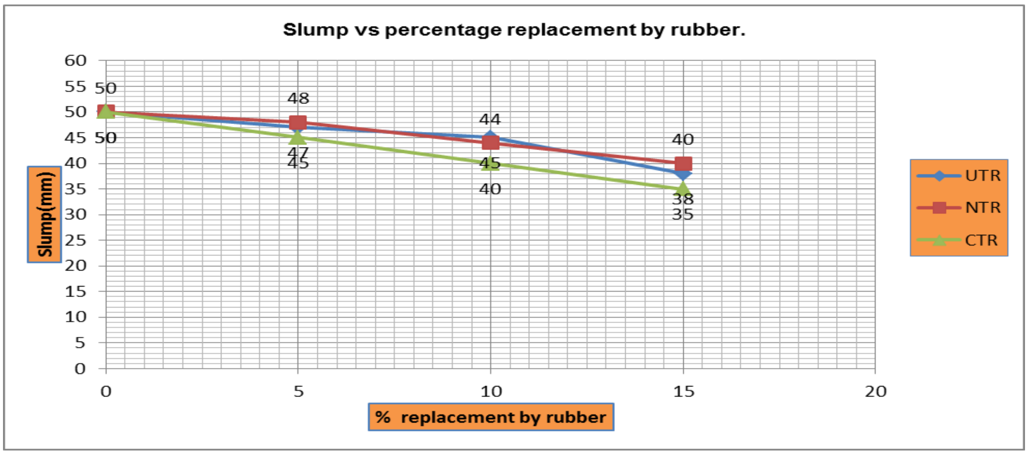

Figure 6:Slump verses percentage replacement of course aggregates by rubber

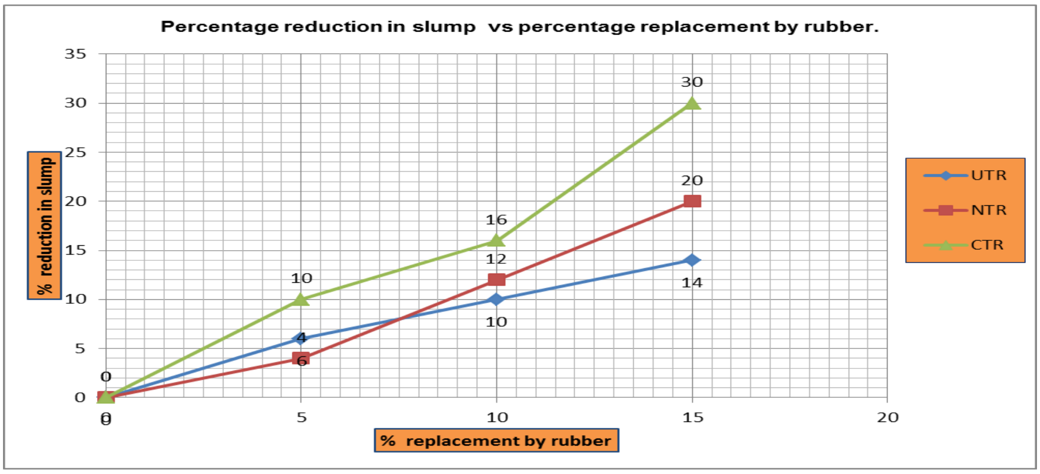

Figure 7: Percentage reduction in slump verses percentage replacement of course aggregates by rubber

From the test results of hardened concrete it is clear that compressive,flexural and split tensile strength of concrete have decreased by the partial replacement of coarse aggregates by rubber. By giving NaOH treatment and cement paste treatment to the shredded rubber the strength of rubber based concrete has increased. The results are more good in case of specimens where NaOH treatment has been given to the rubber aggregates than cement paste treatment.

Under compression testing there was brittle failure in control concrete while the rubber based concrete specimens didn't shown brittle failure.In control specimens there were inclined cracking, while as in rubber based concrete specimens there were horizontal cracks.Compressive strength tests clearly show that the addition of rubber to concrete caused a decrease in the compressive strength of concrete as shown in Figure 8. The decrease in the compressive strength of rubber based concrete is due to lack of proper bonding between cement and rubber particles, low adhesion between rubber and cement matrix, low strength of rubber particles than concrete matrix and large difference of elastic modulus between rubber and other ingredients of concrete. Thus when force is applied, the cracks first of all appear in contact zone of rubber and concrete matrix.After giving surface treatment to the rubber the compressive strength has increased as compared to the untreated rubber based concrete mix. The bond between the rubber aggregates and concrete matrix has improved in case of both the treatments, but the improvement is more prominent in case of NaOH treatment.

After 28 days curing, the percentage decrease in compressive strength of rubber based concrete mixes relative to reference concrete were 27.6%, 14% and 25.4% at 5%, 10% and 15% replacements of coarse aggregates by rubber respectively.While as the percentage increase in the compressive strength of NaOH treated rubber concrete mixes relative to the untreated rubber based concrete were 17.67%, 7.7% and -23% at 5%, 10% and 15% replacements respectively. And in case of cement paste treated rubber concrete mixes the percentage increase in compressive strength were 12%, -34% and 6.4% at 5%, 10% and 15% replacements respectively relative to the rubber based concrete.

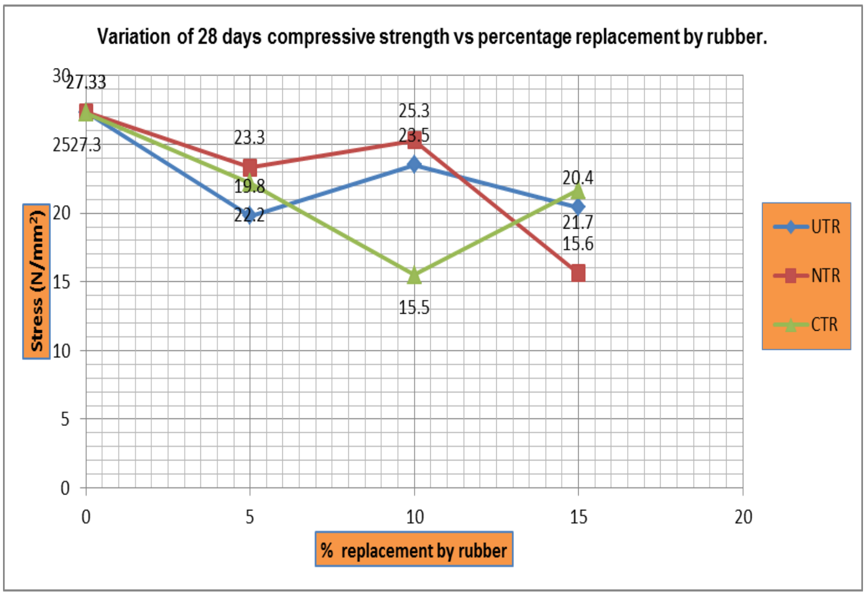

Figure 8 Variation of Compressive Strength with the percentage replacement of course aggregates by rubber

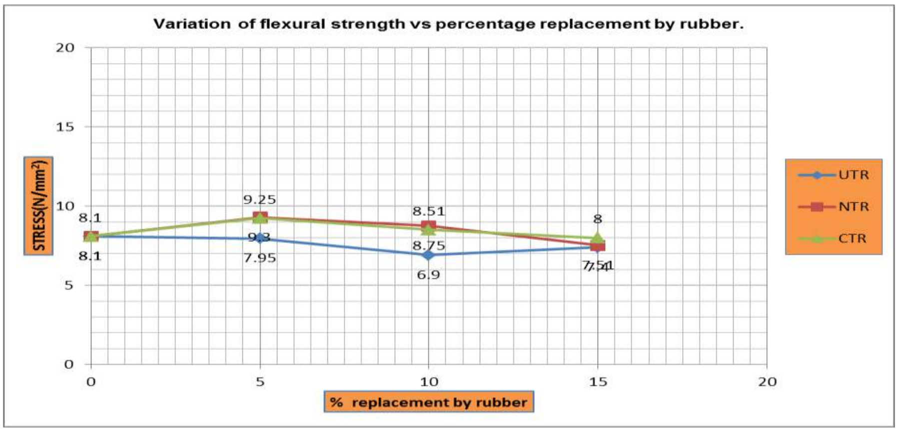

Figure 9: Variation of Flexural Strength with the percentage replacement of course aggregates by rubber

Flexural strength values show that concrete with rubber exhibited decreasing flexural strength with increase in percentage of rubber as shown in Figure 9. At 5% replacement by rubber the decrease in the flexural strength was very less and was comparable to the control concrete. This is because at low percentage the rubber aggregates help in bridging the gaps caused due to the flexural loading Thus the specimen is able to withstand additional load after cracking. At higher percentages of rubber there is remarkable decrease in the flexural strength of concrete due to improper bonding between rubber aggregates and cement paste. After giving surface treatment to the rubber the flexural strength has increased as compared to the untreated rubber based concrete mix. The bond between the rubber aggregates and concrete matrix has improved in case of both the treatments, but the improvement is more prominent in case of NaOH treatment. After 28 days curing, the percentage decrease in flexural strength of rubber based concrete mixes relative to reference concrete were 1.9%, 14.8% and 8.6% for 5%, 10% and 15% replacements of coarse aggregates by rubber respectively. While as the percentage increase in the flexural strength of NaOH treated rubber concrete mixes relative to the untreated rubber based concrete were 17%, 27% and 1.5% at 5%, 10% and 15% replacements respectively. And in case of cement paste treated rubber concrete mixes the percentage increase in flexural strength were 16.35%, 23.33% and 8.1% at 5%, 10% and 15% replacements respectively relative to the rubber based concrete. The flexural strength of treated rubbed based concrete is comparable to that of the control concrete and at lower percentages it is higher than that of the control concrete.

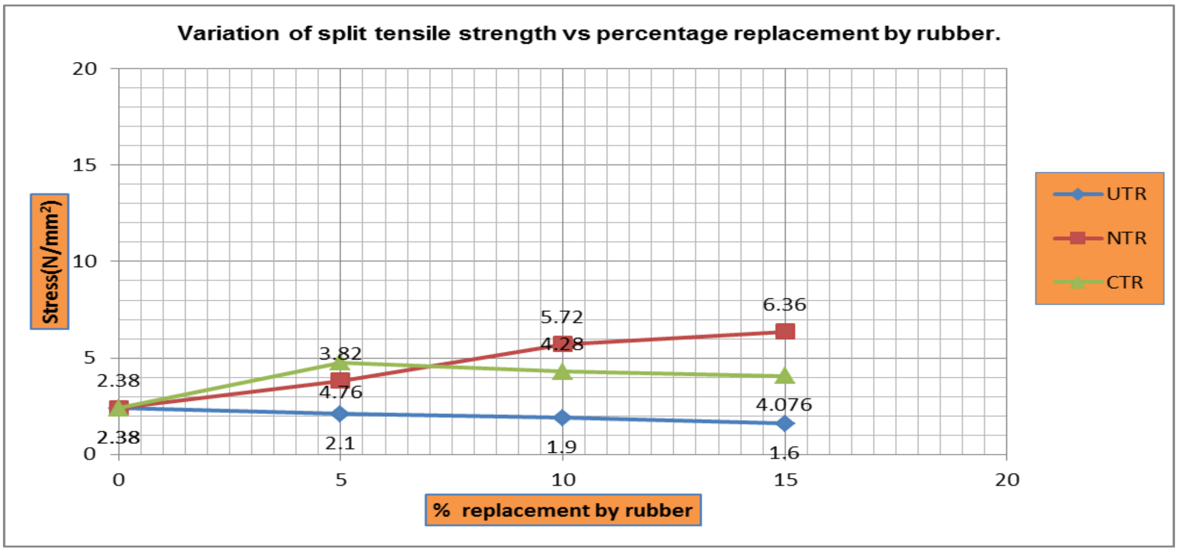

Figure 10: Variation of Split Tensile Strength with the percentage replacement of course aggregates by rubber

Splitting tensile strength values show that concrete with rubber showed a significant decrease in splitting tensile strength with an increase in percentage replacement of coarse aggregates by rubber as shown in Figure 10. After giving surface treatment to the rubber the split tensile strength has increased as compared to the untreated rubber based concrete mix. The bond between the rubber aggregates and concrete matrix has improved in case of both the treatments, but the improvement is more prominent in case of NaOH treatment. After 28 days curing, the percentage decrease in splitting tensile strength of rubber based concrete mixes relative to reference concrete were 11.8%, 20.16% and 32.8% for 5%, 10% and 15% replacements of coarse aggregates by rubber respectively. While as the percentage increase in the split tensile strength of NaOH treated rubber concrete mixes relative to the untreated rubber based concrete were 82%, 201% and 297% at 5%, 10% and 15% replacements respectively. And in case of cement paste treated rubber concrete mixes the percentage increase in split tensile strength were 126.6%, 125% and 154.7% at 5%, 10% and 15% replacements respectively relative to the rubber based concrete.

From the test results it is clear that the split tensile strength of concrete specimens where treated rubber aggregates have been used is greater than that of the control and it increases with the increase in the percentage of replacement .

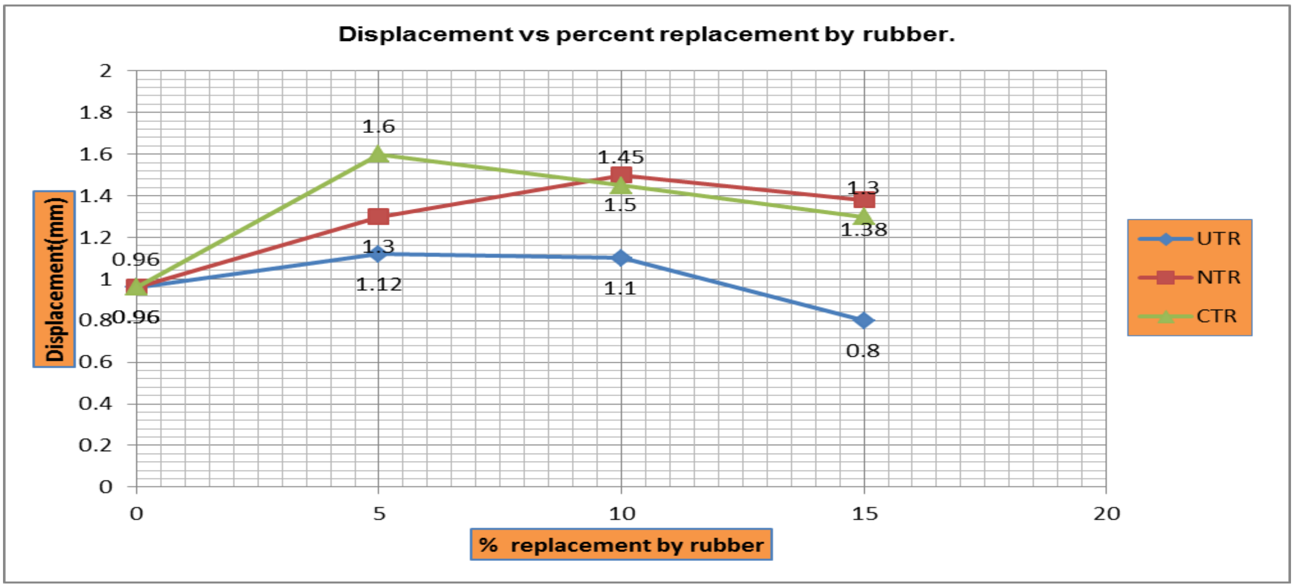

Figure 11: Variation of mid span displacement with the percentage replacement of coarse aggregates by rubber.

From Figure 11 it is clear that there is increase in the mid span displacement with the replacement of coarse aggregates by rubber, with maximum value at 5% replacement. Thus, it can be concluded that the toughness of concrete increases with the replacement of coarse aggregates by rubber. This mid span displacement has further improved by giving surface treatment to the rubber aggregates being maximum for the rubber concrete where cement paste treatment has been given.

IV. CONCLUSION & RECOMMENDATIONS

From this experimental study it can be concluded that the both the surface treatments of rubber aggregates have improved the mechanical properties of rubber based concrete but NaOH treatment has resulted in more improvement than the cement paste treatment. Although by giving surface treatment the mechanical strength of rubber based concrete have improved a lot but the compressive strength of rubber based concrete is still less than that of the control concrete so there is still a lot to be done for improving the compressive strength of rubber based concrete to make it at par with the conventional concrete.

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