INFLUENCE OF PLASTIC AGGREGATE ON BEHAVIOUR OF CONCRETE

Bhupesh Kumar Gupta[1], Mandeep Kaur[1], Mudasir Nazeer[2], Kanish Kapoor[2]

1. Lovely Professional University, Phagwara, India
2. Dr B R Ambedkar National Institute of Technology Jalandhar, India

ABSTRACT. Construction industry is the biggest purchaser of natural aggregates which prompted exhaustion of good quality regular sand (fine aggregates). Stream sand, which is one of the constituents utilized as a part of the creation of ordinary concrete, has turned out to be exceptionally costly and furthermore rare. In the setting of such a depressing climate, plastic aggregates can be used beneficially. In this investigation the reused plastics were utilized to set up the fine aggregates along these lines furnishing an economical alternative to manage the plastic waste. During this study waste Polythene Terephthalate (PET) heated to make PET-agglomerate, then cooled and crushed into aggregates that embrace sort of sizes with definite gradation. Three concrete mixes were created with totally different replacement levels (0%, 50% and 100% by volume) of natural fine aggregate with plastic fine aggregate. Compressive strength test, Split tensile strength test and Water absorption test analysis has been performed in this examination. Outrageous diminishing in workability and density viewed around 95% and 14.4% individually for 100% plastic substance. Decreasing in compressive strength was just around 14% and diminishment in water absorption was around 37% for concrete containing 50% plastic.

Keywords: PET, Fine aggregate, Concrete

Bhupesh Kumar Gupta is a Post Graduate Scholar in School of Civil Engineering, Lovely Professional University, Phagwara, India.
Telephone with Country Code: +919937767773, Email Id: bgsunny847@gmail.com

Mrs Mandeep Kaur is an Assistant Professor and Deputy Dean in School of Civil Engineering, Lovely Professional University, Phagwara, India.
Telephone with Country Code: +918146466998, Email Id: mandeep.kaur@lpu.co.in

Dr Kanish Kapoor is an Assistant Professor of Civil Engineering at Dr B R Ambedkar National Institute of Technology Jalandhar, India.
Telephone with Country Code: +919463359988 Email Id: 4kanishkapoor@gmail.com

Mudasir Nazeer is a Research Scholar in civil Engineering Department at Dr B R Ambedkar National Institute of Technology Jalandhar, India.
Telephone with Country Code: +917889570255, Email Id: mudasir13m@gmail.com

INTRODUCTION

Concrete is the most broadly utilized man made construction material which is blend of cement, aggregates and water. The aggregate part in concrete is around 75 % of its aggregate volume and in this manner it assumes a key part in the general execution of concrete [1]. Construction industry is the biggest purchaser of characteristic assets which prompted exhaustion of good quality regular sand (fine aggregates). Because of colossal development in solid, aggregates are confronting emergency. Stream sand, which is one of the constituents utilized as a part of the creation of ordinary concrete, has turned out to be exceptionally costly and furthermore rare. In the setting of such a depressing climate, there is substantial interest for elective materials from mechanical waste. Plastics are largely utilized and therefore contribute to an ever increasing of the solid waste volume. Among the plastic waste, Polyethylene forms the largest fraction, followed by polyethylene terephthalate (PET).

Polyethylene terephthalate (PET) is one of the most common consumer plastics used and is widely employed as a raw material to realize products such as blown bottles for soft-drink use and containers for the packaging of food and other consumer goods. PET bottles have taken the place of glass bottles as storing vessel of beverage due to its lightweight and easiness of handling and storage. In 2007, it is reported a world's annual consumption of PET drink covers of approximately 10 million tons, which presents perhaps 250 milliards bottles. This number grows about up to 15% every year (ECO PET, 2007). On the other hand, the number of recycled or returned bottles is very low. Utilizing plastic waste as a concrete segment can make an immense transformation in the field of reusing the plastic waste. The execution of PET as concrete part in different structures had been done in solid innovation. For instance, [2,4,5] has researched PET as total for concrete and PET as fiber for concrete. Diminishment in strength because of decrease in bonding with presentation of plastic particles was observed, also the expansive surface zone and shiny texture of PET aggregates makes concrete connection frail outcomes in less compressive strength [2]. The density of PET Concrete decreases contrasted with regular aggregate concrete and bleeding caused by higher w/c proportion in concrete outcome diminish in compressive strength [1,3]. Decrement of tensile strength of 15.9%, 18.06% for w/c ratio of 0.42 and 0.54 was observed with replacement of 15% of sand volume by PET particles[4].

The current study aimed to evaluate the influence of fine aggregates replacement with PET at the rate of 0%, 50% and 100%. Compressive strength test, Split tensile strength test were performed at the age of 7 and 28 day respectively. Also workability, Density and Water absorption test analysis has been performed in this examination.

EXPERIMENT

Preparation of Specimen

In this study, three concrete mixtures were prepared. The first one is standard Control Mix (CM) contains completely natural fine aggregates and the other two M_1 and M_2 were replaced by 50% and 100% of PFA respectively. Replacement of NFA with PFA has done by volume. Relating to the specific gravity, the volume of NFA has replaced by a similar volume of PFA. Indian standard suggested rules for mix proportion incorporate the outline of normal concrete mixes, for both medium and high strength concretes. Volume of water, cement and aggregate were found out by following IS: 10262 by settling the w/c proportion to 0.45.

Cement utilized as a part of this investigation as a coupling material was Ordinary Portland Cement of grade 43 (OPC-43). Normal crushed stone was utilized as NCA in this investigation. River sand was utilized as NFA in this examination. To make simpler the liquefying procedure, washed PET containers were cut into little pieces (chips) physically with the assistance of scissors. The PET flakes are then heated until the point that they gain their fluid state. The fluid PET at that point filled the embellishment plate and let to be cooled. The shaped PET was then pulverized to frame the aggregate with help of hammer. After generation of PFA, they were kept immersed in water for 24hours and dried under sun for 3 hours to bring aggregates from dry condition to saturated condition.

Table 1 Physical properties of cement

PROPERTY	RESULT	IS RECOMMENDATION (IS:8112,2013)
Fineness	9.5%	10% (maximum)
Specific Gravity	3.15	3.15
Consistency	29.75%	26%-33%
Initial Setting Time	70 minutes	30 minutes (minimum)
Final Setting Time	425 minutes	600 minutes (maximum)

Table 2 Properties of NCA

PROPERTY	VALUE	IS RECOMMENDATION
Crushing Value	7.35%	30%
Water Absorption	1%	0.1%-2%
Specific Gravity	2.7	2.6-2.9
Elongation Index	10.31%	Combined flakiness and elongation index so obtained should not exceed 40 %
Flakiness Index	15.39%	

Table 3 Properties of NFA

PROPERTY	VALUE	IS RECOMMENDATION
Water Absorption	2%	3% (maximum)
Specific Gravity	2.6	2.4-3

Table 4 Properties of PFA

Property	Value
Water Absorption	Nil
Specific Gravity	1.38

Table 5 Mix Proportion

Constituents	Quantity (Kg/m^3)
Cement	438
Water	198
Fine Aggregate	640
Coarse Aggregate	1130

Table 6 Composition of mix prepared

MIX NOTAT-ION	MIX COMPOSITION (VOL. %)	CONSTITUENTS				
		Cement (Kg/m^3)	Coarse aggregate (Kg/m^3)	NFA (Kg/m^3)	PFA (Kg/m^3)	Water (Kg/m^3)
CM	(NFA) $_{100\%}$ + (PFA) $_{0\%}$	438	1130	640	-	198
M_1	(NFA) $_{50\%}$ + (PFA) $_{50\%}$	438	1130	320	170	198
M_2	(NFA) $_{0\%}$ + (PFA) $_{100\%}$	438	1130	-	340	198

Testing of Hardened Concrete

Compressive strength

The compressive strength of concrete specimens was found out at curing age of 7 and 28 days. All specimens casted for the test were cubical in shape and of size 100mm. Three specimens for each blend and each curing age were tested to determine compressive strength of concrete. The test was done at room temperature on digitalized Compression Testing Machine (CTM) with a maximum load limit of 1000KN avowing to IS:516 [29]. All specimens were tested straight after extraction from water at surface dry condition. The compressive strength of concrete for each blend was then computed from the average crushing strength of three specimens.

Workability

The slump test was performed to determine the workability of concrete. The check confirms to IS:1199 [28]. Slump for each blend was computed at time of casting of specimens with the assistance of slump cone apparatus. The concrete was packed in 3 layers; each layer was about 33% the pinnacle of the slump cone and each had relations with was stroked 25 times with the rounded end of tamper. Once the cone loaded down with concrete, it was upraised vertically in 3 seconds and the slump values were recorded.

Split tensile strength

Split tensile strength of concrete was determined at curing age of 28 days. Cylinder shaped specimens of diameter 100mm and tallness 200mm were casted for the test. The same CTM used in compressive strength test was used to found out split tensile strength. Three specimens from each blend were tested to know the tensile strength of concrete. All specimens were tested straight after expulsion from water at surface dry condition. The split tensile strength of concrete for each blend was then ascertained from the average crushing strength of three specimens.

Water absorption

To perform water absorption test cubes of size 100mm were casted and test affirms ASTM C 642-97 [30]. Three specimens of each blend were tested for the examination. The specimens were removed from water following 28 days of curing and conveyed to surface dry condition. At that point their weight were recorded and kept in oven up a steady temperature of 110^0C ± 5^0C for a time of 24hours so as to evacuate dampness. At that point they were permitted to cool under room temperature and weights were recorded. Then again specimens are immersed in water bath for 24 hours and weighted again. The measure of water consumed (%) was determined utilizing Equation below.

$$\frac{W_2 - W_1}{W_1} \times 100$$

Where; W1 and W2 are mass of dry and wet specimens respectively.

RESULT AND DISCUSSION

Compressive strength

The compressive strength results of concrete mixes at different curing periods containing varying replacement percentage of NFA with PFA were presented in Fig.-1. It was observed that the introduction of PFA as a replacement of NFA decreases the compressive strength of the concrete mix. For example, a decrease of 1.26% in the compressive strength was observed at the curing age of 7 days with 50% replacement of NFA with PFA when compare to the control mix. Furthermore, a significant decrease in compressive strength was observed at curing age of 28 days, as the decrease was 13% when compared to control mix. Moreover, this decrease in the compressive strength becomes more significant with complete replacement of NFA with PFA. For example, a significant decrease of 43% was observed in the compressive strength of the concrete mix as compare to the control mix at the curing period of 7 days, when NFA were completely replaced with PFA. Whereas at the curing age of 28 days, 50% decrease in compressive strength was observed when compared with control mix where replacement of NFA with PFA was 100%.

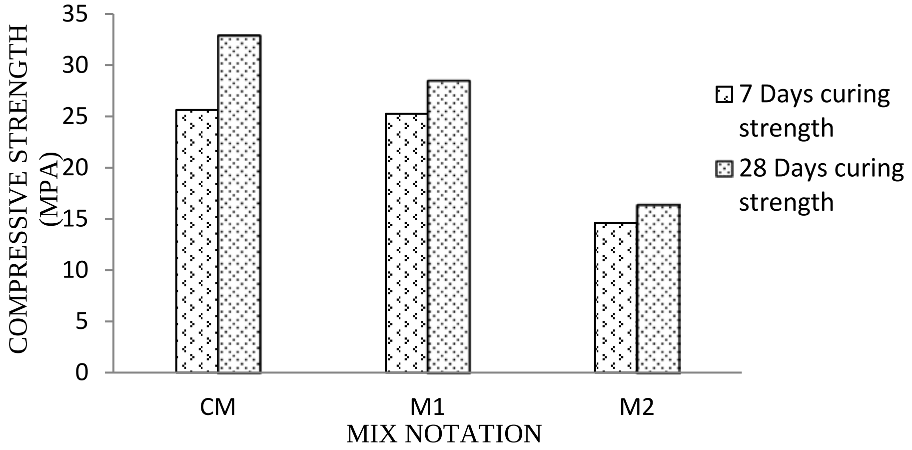

Figure 1 Compressive strength of concrete at various level of PFA content

Workability

A graphical correlation of workability of different blends with and without PFA is shown in Fig-2. The workability curve demonstrates critical reduction in workability of blends with PFA contrasted with blend without PFA. A direct lessening in workability has been observed for M_1, M_2. The decrease in workability for mix M1 was observed as 87.5% when compared with control mx CM. and much significant decrease in workability was observed in case of mix M2, where the decrement was 95% when compared with standard control mix CM.

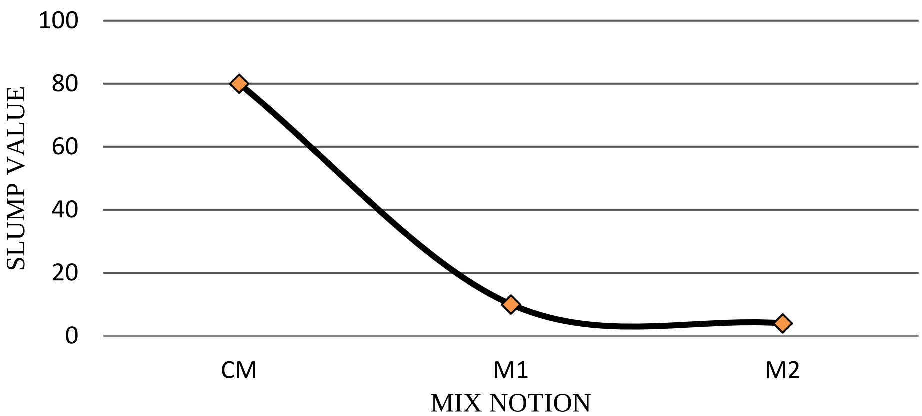

Figure 2 Correlation of workability of different blends with and without PFA

Split tensile strength

The split tensile strength results of various concrete mixes are shown in Fig 3. The figure shows graphical comparison of tensile strengths of various concrete mixes with and without PFA. Significant decrease in tensile strength was observed for mixes 50% and 100% PFA compared to Mix without PFA. The decrease in tensile strength was observed as 18.66% for concrete mix M1 when compared to standard control mix CM. And more significant decrease in tensile strength was seen in case of second concrete mix M2 where the decrease in tensile strength was 20.52% as compared to control mix CM. Lessening of tensile strength might be attributed to weaker bonding of concrete mixture.

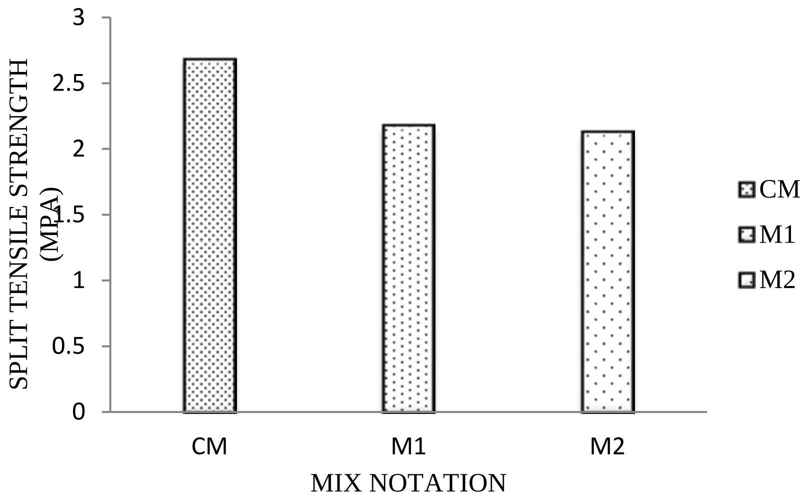

Figure 3 - Variation in Split tensile strength of concrete at various level of PFA content

Water absorption

The various result of water absorption on different concrete mixes was presented in Fig.-4. It was observed from the figure that with the introduction of 50% PFA as a replacement of NFA, the water absorption of the concrete mix were found to be reduced. A significant decrease of approximately 37% was observed with the replacement of 50% NFA with PFA. Moreover, with the increasing percentage of PFA as a replacement of NFA increases the water absorption of the concrete matrix but this increase in water absorption was still less than that of the control mix by 0.88%.

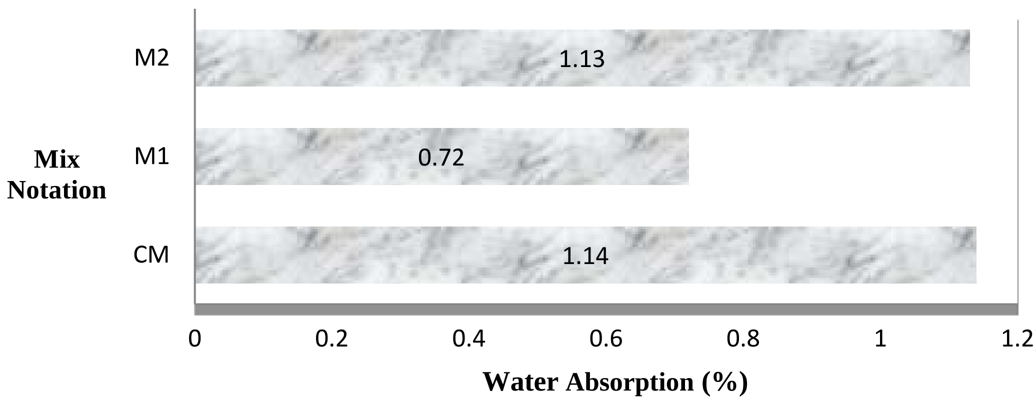

Figure 4- Water absorption as a function of PFA content

CONCLUSIONS

The use of 0%, 50%, 100% PFA replaced concrete mixture results in following conclusions: Lessening in density has been observed as 14.4% for replacing completely which is extreme of all level of substitution. The extreme reduction in workability has been observed as 95% for complete replacement. Mix with 50% PFA is indicating better outcome with just around 14% decrement in compressive strength.Extreme lessening in water absorption occurred about 37% for mix containing 50% PFA. From an ecological point of view, economic and energy-conserving benefits are possible from the incorporation of waste PET, without any particular treatment, in concrete. The main advantage of recycling PET in concrete is that this plastic material does not have to be purified, nor is the removal of colours required, like in other common PET recycling applications.

REFERENCES

1. R. V. SILVA, J. DE BRITO, N. SAIKIA, Influence of curing conditions on the durability-related performance of concrete made with selected plastic waste aggregates, Cement and Concrete Composites. 35 (2013) 23–31. doi:10.1016/j.cemconcomp.2012.08.017.
2. NURSYAMSI, W.S.B. ZEBUA, The Influence of Pet Plastic Waste Gradations as Coarse Aggregate Towards Compressive Strength of Light Concrete, Procedia Engineering. 171 (2017) 614–619. doi:10.1016/j.proeng.2017.01.394.
3. M.J. ISLAM, M.S. MEHERIER, A.K.M.R. ISLAM, Effects of waste PET as coarse aggregate on the fresh and harden properties of concrete, Construction and Building Materials. 125 (2016) 946–951. doi:10.1016/j.conbuildmat.2016.08.128.
4. E. RAHMANI, M. DEHESTANI, M.H.A. BEYGI, H. ALLAHYARI, I.M. NIKBIN, On the mechanical properties of concrete containing waste PET particles, Construction and Building Materials. 47 (2013) 1302–1308. doi:10.1016/j.conbuildmat.2013.06.041.
5. A.M. DA SILVA, J. DE BRITO, R. VEIGA, Incorporation of fine plastic aggregates in rendering mortars, Construction and Building Materials. 71 (2014) 226–236. doi:10.1016/j.conbuildmat.2014.08.026.
6. SEMIHA AKÇAÖZOǦLU, C.D. ATIŞ, K. AKÇAÖZOǦLU, An investigation on the use of shredded waste PET bottles as aggregate in lightweight concrete, Waste Management. 30 (2010) 285–290. doi:10.1016/j.wasman.2009.09.033.
7. M. FRIGIONE, Recycling of PET bottles as fine aggregate in concrete, Waste Management. 30 (2010) 1101–1106. doi:10.1016/j.wasman.2010.01.030.
8. G. SEETHARAMAN, The Economic Times, ET Bureau. (2017). https://economictimes.indiatimes.com/articleshow/59301057.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst.
9. DAVE, 15,343 tn plastic waste generated in India everyday, Press Trust of India. (2016). http://www.business-standard.com/article/pti-stories/15-342-tn-plastic-waste-generated-in-india-everyday-dave-116080200866_1.html.
10. W.C. LI, H.F. TSE, L. FOK, Plastic waste in the marine environment: A review of sources, occurrence and effects, Science of the Total Environment. 566–567 (2016) 333–349. doi:10.1016/j.scitotenv.2016.05.084.
11. C. P. THOSAR, DR.M.HUSAIN, Reuse of Plastic Waste as Replacement of Sand in Concrete, International Journal of Innovative Research in Science, Engineering and Technology. 6 (2017) 789–794.
12. H. ALTER, The Origins Of Municipal Solid Waste: II. Policy Options For Plastics Waste Management, Waste Management & Research. 11 (1993) 319–332. doi:10.1006/wmre.1993.1034.
13. BUREAU OF INDIAN STANDARD, IS :383; Specification for Coarse and Fine Aggregate From Natural Sources for Concrete, 1970.
14. P. PREM KUMAR, C.G. SARAVANAN, M. GOPALAKRISHNAN, Conversion of Hospital Low Density Polyethylene Waste into Hydrocarbons Using Fly Ash as Catalyst, International Journal of Engineering Trends and Technology. 16 (2014) 241–251. doi:10.14445/22315381/IJETT-V16P249.

15. P. SINGH, V.P. SHARMA, Integrated Plastic Waste Management: Environmental and Improved Health Approaches, Procedia Environmental Sciences. 35 (2016) 692–700. doi:10.1016/j.proenv.2016.07.068.
16. A.K. JASSIM, Recycling of Polyethylene Waste to Produce Plastic Cement, Procedia Manufacturing. 8 (2017) 635–642. doi:10.1016/j.promfg.2017.02.081.
17. T. CHILTON, S. BURNLEY, S. NESARATNAM, RESOURCES , Conservation and Recycling A life cycle assessment of the closed-loop recycling and thermal recovery of, "Resources, Conservation&Recycling."54(2010) 1241–1249. doi:10.1016/j.resconrec.2010.04.002.
18. A. BREAMS, J. BAEYENS, R. DEWIL, Recycling and Recovery of Post-consumer Plastic Solid Waste in a European Context, Thermal Science. 16 (2012) 669–685. doi:10.2298/TSCI120111121B.
19. Y.W. CHOI, D.J. MOON, J.S. CHUNG, S.K. CHO, Effects of waste PET bottles aggregate on the properties of concrete, Cement and Concrete Research. 35 (2005) 776–781. doi:10.1016/j.cemconres.2004.05.014.
20. PRAVEEN MATHEW ;, A.K. P, P. PRAKASH, T. BARRIED, V. P, Comparative Study on Waste Plastic Incorporated Concrete Blocks with Ordinary Concrete Blocks, International Research Journal of Engineering and Technology. 3 (2016) 1894–1896.
21. MD. JAHIDUL ISLAM, A. K. M. RAKINUL ISLAM, MD. SALAMAH MEHERIER, An Investigation on Fresh and Hardened Properties of Concrete while Using Polyethylene Terephthalate (PET) as Aggregate, International Scholarly and Scientific Research & Innovation. 9 (2015) 558–561. http://waset.org/publications/10001238/an-investigation-on-fresh-and-hardened-properties-of-concrete-while-using-polyethylene-terephthalate-pet-as-aggregate.
22. A. HASSANI, H. GANJIDOUST, A.A. MAGHANAKI, Use of plastic waste (poly-ethylene terephthalate) in asphalt concrete mixture as aggregate replacement, Waste Management & Research. 23 (2005) 322–327. doi:10.1177/0734242X05056739.
23. B. SAFI, M. SAIDI, D. ABOUTALEB, M. MAALLEM, The use of plastic waste as fine aggregate in the self-compacting mortars: Effect on physical and mechanical properties, Construction and Building Materials. 43 (2013) 436–442. doi:10.1016/j.conbuildmat.2013.02.049.
24. L. FERREIRA, J. DE BRITO, N. SAIKIA, Influence of curing conditions on the mechanical performance of concrete containing recycled plastic aggregate, Construction and Building Materials. 36 (2012) 196–204. doi:10.1016/j.conbuildmat.2012.02.098.
25. M. HOSSAIN, P. BHOWMIK, K. Shaad, Use of waste plastic aggregation in concrete as a constituent material, Progressive Agriculture. 27 (2016) 383. doi:10.3329/pa.v27i3.30835.
26. B. HARINI, K. V RAMANA, Use of Recycled Plastic Waste as Partial Replacement for Fine Aggregate in Concrete, International Journal of Innovative Research in Science, Engineering and Technology. 4 (2015) 8596–8603. doi:10.15680/IJIRSET.2015.0409106.
27. BUREAU OF INDIAN STANDARDS, IS: 1199 - 1959; Methods of sampling and analysis of concrete, 1959.
28. BUREAU OF INDIAN STANDARDS, IS 516 -1959: Method of Tests for Strength of Concrete, 2004.
29. AMERICAN SOCIETY FOR TESTING OF MATERIALS COMMITTEE C-9, ASTM C 642 – 97 Standard Test Method for Density Absorption , and Voids in Hardened Concrete, (1997).