China Petroleum Processing and Petrochemical Technology

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 725-736

AN EXPERIMENTAL STUDY ON RUBBERIZED CONCRETE

Ankit Kumar Sharma
Student, Greater Noida Institute of Technology affiliated to Dr. A.P.J Abdul Kalam Technical University, Lucknow.

Anuj kumar Sharma
Assistant Professor, Greater Noida Institute of Technology affiliated to Dr. A.P.J. Abdul Kalam Technical University, Lucknow.

Abstract:

The experimental investigation delved into the resilience and pliability of traditional concrete and TRAC (rubberized concrete). A total of twelve samples were subjected to testing, comprising of control samples composed of traditional concrete and TRAC samples that integrate partially substituted rubberized components. The samples were exposed to impact evaluations utilising a plummet weight impact assessment technique. The effect potency, power consumption, and malleability indicator were assessed. The findings indicated that TRAC considerably enhanced the durability and malleability properties of cement in contrast to traditional cement. TRAC utilising fine aggregate substitution exhibited comparable performance in impact and malleability, whereas TRAC utilising coarse aggregate substitution demonstrated enhanced malleability. The research findings inferred that the implementation of rubberized concrete can amplify the shock-absorbing and malleability properties of concrete edifices, which is crucial for seismic planning and energy attenuation in extreme circumstances.

Keywords: Rubberized concrete, Impact resistance, Ductility, Energy absorption, Drop weight testing.

1. INTRODUCTION

When it comes to designing reinforced concrete structures, it is crucial to take into account the concept of ductility. This is because it plays a vital role in determining how the moment is redistributed and how well the structure can absorb and dissipate energy during post-elastic deformations. In other words, the ability of a structure to withstand and recover from deformations is directly linked to its ductility. Therefore, it is imperative to carefully consider this factor during the design process to ensure that the structure can withstand any potential stresses and strains that it may encounter over its lifetime. In order to assess the energy dissipation and ductility of a material or structure, it is necessary to perform impact tests. These tests involve subjecting the material or structure to a sudden and forceful impact, which allows researchers to observe how the material responds to stress and strain. By measuring the amount of energy that is absorbed by the material during the impact The primary objective of this research is to investigate the behaviour of cylindrical specimens that are manufactured using two different types of concrete materials, namely conventional concrete and rubberized concrete (TRAC), when subjected to impact loads. The study aims to provide valuable insights into the performance of these materials under such conditions, which can be useful in various construction applications. By conducting a series of tests and analyses, the researchers hope to gain a better understanding of the properties and characteristics of these materials, and how they can be optimised for enhanced impact resistance. Overall, this study is a significant contribution to the field of concrete materials research and has the potential to inform future developments in this area The primary objective of this study is to evaluate and analyse the impact strength and ductility index of TRAC (Textile Reinforced Aerated Concrete) in comparison to conventional concrete. The research aims to provide a comprehensive understanding of the mechanical properties of TRAC and how they differ from those of traditional concrete. By conducting a thorough investigation and comparison of these two materials, the study seeks to contribute to the advancement of knowledge in the field of construction materials and pave the way for the development of more efficient and sustainnable building practises. The research conducted has shed light on the promising prospects of utilising TRAC, or textile reinforced alkali-activated concrete, as a means of enhancing the energy dissipation and ductility properties of concrete structures. These particular attributes are of paramount importance when it comes to seismic design and the overall resilience of such structures. By exploring the potential of TRAC, this study has contributed to the ongoing efforts to improve the safety and durability of concrete structures in the face of seismic activity.

When it comes to the design of reinforced concrete structures, there are a number of key factors that must be taken into account in order to ensure that the final product is both strong and serviceable. However, one additional consideration that is often overlooked is the concept of ductility. By incorporating ductility into the design requirements, engineers can help to ensure that the structure is able to withstand a wide range of stresses and strains without suffering from catastrophic failure. This can be especially important in areas that are prone to earthquakes or other natural disasters, where the ability of a structure to remain intact and functional can be a matter of life and death. Ultimately, by taking a The significance of this particular aspect cannot be overstated as it plays a crucial role in ascertaining the extent to which the redistribution of moment can be carried out in limit state design. In the realm of seismic design, it is crucially significant to consider the ability of a structure to withstand the impact of a powerful earthquake. In order to ensure that a building can endure such a force of nature, it must possess the capacity to absorb and dissipate energy through post-elastic deformations.

This means that the structure must be able to flex and bend in response to the seismic waves, rather than remaining rigid and brittle, which could result in catastrophic damage or collapse. Therefore, the ability to withstand post-elastic deformations is a key factor in the seismic design of any structure. In order to gain a comprehensive understanding of the energy dissipation and ductility of a material or structure, it is crucial to carry out an impact test. This type of test involves subjecting the material or structure to a sudden and forceful impact, which can reveal important information about its ability to absorb and dissipate energy, as well as its overall toughness and resilience. By carefully analysing the results of an impact test, engineers and researchers can gain valuable insights into the performance characteristics of a wide range of materials and structures, which can inform the design and development of new In the present chapter, a concerted effort has been made to undertake the casting and subsequent testing of cylindrical specimens that have been fabricated using both conventional concrete and TRAC. The primary objective of these tests is to evaluate the response of these specimens when subjected to impact loads.

2. METHODOLOGY

Test Specimens

Several experiments were carried out to investigate the effect potency and pliability ratio of TRAC. A complete of twelve examples classified into four categories were experimented in this project. Every cluster was comprised of three indistinguishable examples. Whilst the initial set of specimens, categorised as control specimens, were composed of traditional concrete, the remaining three sets were produced using concrete that incorporated a proportion of rubberized material, known as TRAC. The second group of specimens were fabricated using 6% rubber crumbs as a substitute for FA, whereas the third group of specimens were formulated with 6% rubber chips in lieu of CA. Within the fourth group, both FA and CA underwent a partial substitution process utilising finely granulated rubber particles and rubber fragments.

Table 2.1 Mix Proportions with Ingredients

Specimen ID	Grade	Cement (kg/m3)	Fine Aggregate (kg/m3)		Coarse Aggregate (kg/m3)		W/C Ratio	Slump (mm)
			Sand	FR	Jelly	CR		
R0	M20	50	71.4	0	151.24	-	0.5	4.5
R1		50	67.12	4.28	151.24	-	0.5	4.2
R2		50	71.4	-	142.17	9.07	0.5	9
R3		50	69.26	2.14	146.7	4.54	0.5	9.74

Each and every sample within this collection had a diameter of 150 millimetres and a height of 64 millimetres. The concoction has been delivered to procure concrete of M20 quality in accordance with IS: 10262 – 2009 and as specified in Table 4.1. A vacant cylindrical cast of 150 mm diameter and 64 mm altitude was produced using a readily obtainable PVC conduit. The casts were situated atop a solidified foundation and it was packed into the cast with appropriate densification. Following a day of waiting, the cylindrical samples were extracted from their moulds and transferred to a tank for curing, where they remained for a duration of 28 days. Following a 28-day period of solidifying, the samples were desiccated by natural means and subsequently coated with a layer of whitewash prior to examination. The mathematical particulars of the moulded samples are provided in Chart 2.2. Together with the cylindrical samples, supplementary specimens were also fabricated and evaluated for their mechanical characteristics and are exhibited in Table 2.3.

Table 2.2 Specimen Details

Group	Specimen ID	Types of Specimens	Size (mm)	No. of Specimens
I	R0	Conventional Concrete	150 x 64 Ht. mm	3 Nos.
II	R1	Fine Aggregate Replacement with 6% Rubber Crumbs	150 x φ φ φ 64 Ht. mm	3 Nos.
III	R2	Coarse Aggregate Replacement with 6% Chiseled Truck Tyre Chips	150 x 64 Ht. mm	3 Nos.
IV	R3	3% Rubber Crumbs & 3% Chiseled Truck Tyre Chips Replacements with FA & CA	150 x 64 Ht. mm φ	3 Nos.

Test Setup

The testing framework apparatus constructed in the laboratory in accordance with the suggestions of the ACI 544.2R89 committee, comprises of a customary hand-operated 3.5 kg compression mallet with a 48 inch descent (1.22 m); a 64mm diameter toughened steel sphere and a level foundation plate with placement clamp (Figure 4.1). The girth of the sample was confirmed to the closest milli metre at its midpoint and at the extremities of a diameter before the examination. The sample was situated on the foundation platter with the polished surface facing upwards and aligned within the four pillars of the collision assessment apparatus. The support with the tubular casing was secured firmly and the toughened metal sphere was positioned atop of the sample inside the support. The descending mallet was subsequently positioned with its foundation on the metallic sphere and grasped in an upright position. The mallet was released incessantly, and the tally of strikes needed for the initial noticeable fissure to emerge at the uppermost layer of the sample and for eventual collapse must be documented.

Figure 2.1 Drop Weight Impact Test Setup

The initial fissure was detected through ocular examination. Applying a coat of whitewash on the surface of the sample aided in the detection of this fissure. The ultimate fiasco is characterised by the quantity of impacts needed to initiate fissures in the sample adequately to permit shattered fragments to contact three out of the four placement limbs on the foundation slab. The phases of absolute collapse were distinctly acknowledged by the fragmented sample colliding with the limbs of the foundation panel. The fracturing of standard impact samples was exhibited in Figure 2.5.

3. EXPERIMENTAL RESULTS

The assessment of the toughness of the material was conducted by performing a test on a cylindrical sample with measurements of 150mm x 64mm. A 3.5kg steel sphere was dropped from a predetermined altitude of 1.22m. The data was collected at the onset of the fissures in the concrete specimens and also at the point of complete destruction. The vitality exhausted by the sample until collapse was deemed as a gauge of its shock endurance.

The energy usage was assessed using the subsequent formula:

Energy = Mass (kg) x Height (m) x g (m/sec2) where, the height is equal to the summation of heights to failure.

The examination outcomes were acquired by scrutinising the M20 rank customary cement and TRAC recorded in Table 3.1.

Table 3.1 Impact Test Results for M20 Grade TRAC Specimens

	Mech. Properties (N/mm2)	No. of Blows for	No. of Blows for Ultima	Energy Consumed @ First Crack (Joul)	Energy Consumed @ Ultimate Failure (Joul)	

Specimen ID			First Crack	te Failure					Ductility Index	
	fck	ft			E1	E1Avg	E2	E2Avg	(E2/E-1)	(E2/E1)Avg
R01	26.67	2.12	39	43	1633.66	1577.81	1801.21	1731.4	1.1	1.1
R02	29.11	2.12	38	41	1591.77		1717.44		1.08	
R03	24.66	1.91	36	40	1507.99		1675.55		1.11	
R11	25.92	2.2	31	33	1298.55	1298.55	1382.33	1410.25	1.06	1.09
R12	24.98	2.15	30	33	1256.66		1382.33		1.1	
R13	26.45	2.02	32	35	1340.44		1466.11		1.09	
R21	29.86	2.45	22	26	921.55	907.59	1089.11	1061.18	1.18	1.17
R22	29.64	2.38	21	24	879.66		1005.33		1.14	
R23	29.84	2.4	22	26	921.55		1089.11		1.18	
R31	23.29	1.78	45	49	1884.99	1815.18	2052.55	2052.55	1.09	1.13
R32	21.96	1.69	44	52	1843.1		2178.21		1.18	
R33	23	1.84	41	46	1717.44		1926.88		1.12	

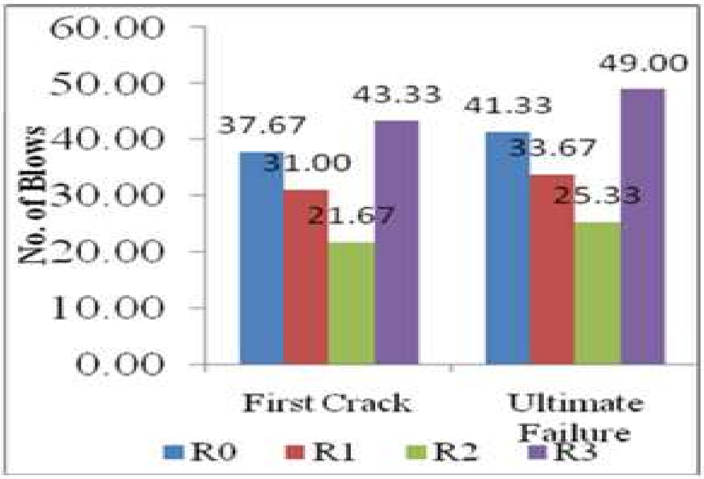


Figure 3.1 No. of Blows Vs TRAC

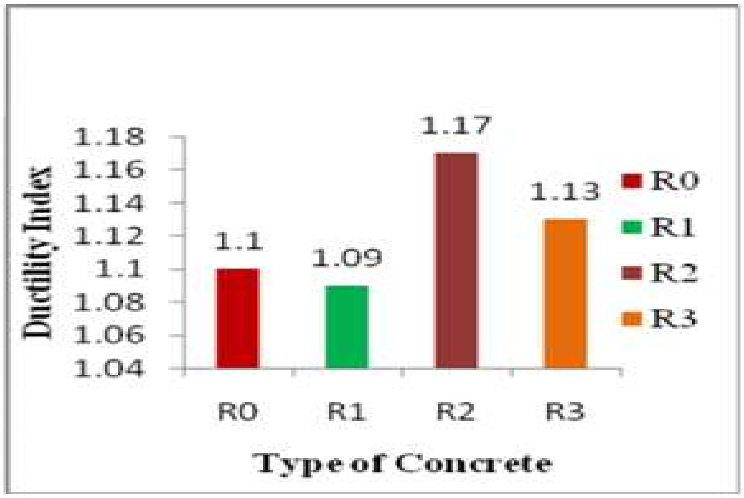


Figure 3.2 Ductility Index Vs TRAC

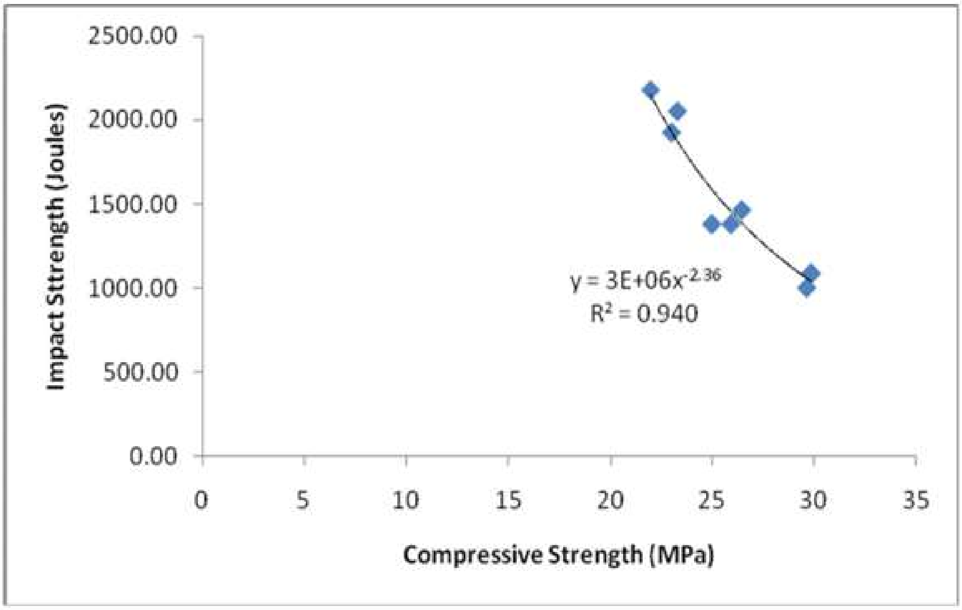


Figure 3.3 Relationship between fck Vs Impact Strength of TRAC

Figure 3.4 Failure Pattern of R3, R2, R1 & R0 Specimen

4. DISCUSSION OF TEST RESULTS

Impact Strength

It is apparent from the illustration 4.2 that the R3 category of TRAC enhanced the shock resistance of cement and the enhancement was roughly 20% more than that of traditional cement. The R1 cement sample exhibited an 83% increase in impact resistance compared to the standard sample, while the R2 sample only demonstrated a 61% improvement over traditional concrete.

Ductility Index

Malleability can be numerically expressed by a metric known as malleability metric, which can be characterised as the proportion of energy assimilated at the point of collapse to the energy assimilated at the initial fissure. Illustration 4.3 displays the pliability measurements for TRAC in relation to M20 calibre. The investigation revealed that the pliability indicator measurements were greater for the R2 category of cement and the magnitude was discovered to be 6.5% more elevated than the customary cement. R3 escalates by 2.7% and R1 executes almost the same as the traditional cement in pliable demeanour.

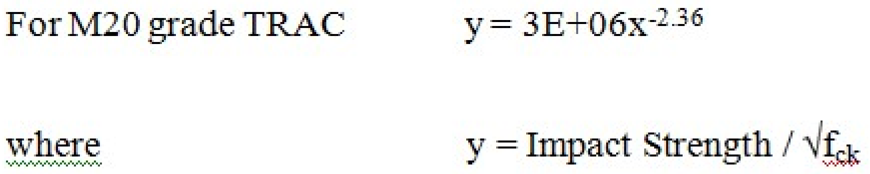
Energy Absorption

The TRAC containing both delicate and rough rubber fragments assimilated an additional 18.55 % of energy in comparison to the standard concrete. The TRAC made of exquisite rubber granules assimilates almost 80% of energy from the traditional concrete, whereas the TRAC composed of rough rubber granules only assimilates 37% of energy in comparison to the standard sample.

THEORETICAL MODEL

Anticipation of Consequence Resilience from adversity.

The association amid influence and fck has been deduced through regression scrutiny from the empirical outcomes depicted in Figure 4.4, and the interrelation acquired was provided in formula (4.1) for TRAC of M20 calibre.



For M20 grade TRAC $y = 3E{+}06x^{-2.36}$

where $y = \text{Impact Strength} / \sqrt{f_{ck}}$

In this investigation, a parallel is drawn between hypothetical and empirical outcomes and recorded in Chart 4.1.

Table 4.1 Comparison between theoretical and Experimental Results Impact Strength & fck

Specimen ID	TRAC (M20 Grade) (N/mm2)				
	fck	Impact Strength	y Exp	y The	Ratio
R11	25.92	1382.33	271.51	271.72	1

R12	24.98	1382.33	276.58	302	0.92
R13	26.45	1466.1	285.07	256.44	1.11
R21	29.86	1089.11	199.31	181.29	1.1
R22	29.64	1005.33	184.66	185.16	1
R23	29.84	1089.11	199.38	181.63	1.1
R31	23.29	2052.55	425.31	368.99	1.15
R32	21.96	2178.21	464.82	436.57	1.06
R33	23	1926.88	401.78	382.45	1.05
Mean			300.94	285.14	

By utilising the average numerical quantity, the Impression Potency has the potential to be restated.

Impact Strength = $300.94\sqrt{fck}$ in case of M20 Grade TRAC (4.3)

5. KEY FINDINGS

- After carrying out experimental explorations on the impact durability of traditional concrete and TRAC, the ensuing observations were noted concerning the impact resistance.
- The utilisation of TRAC incorporating 6% substitution of rubberized materials for both fine and coarse aggregate significantly enhances the impact resistance and pliability properties.
- The utilisation of shredded tyre rubber aggregate as a replacement for 6% of fine aggregate in TRAC results in comparable performance in terms of concrete's impact resistance and malleability.
- The utilisation of chiselled truck tyre rubber as a replacement for 6% of coarse aggregate in TRAC results in a notable enhancement in the ductility feature compared to that of unadorned concrete.
- The Schrader's technique for drop-weight impact testing employed in the current research provides a dependable approximation of the concrete composite's impact durability. Therefore, this examination apparatus is cost-effective, uncomplicated, and easily transportable, can be utilised to assess the shock resistance of cement.

6. CONCLUSION

In the course of conducting an experimental study on the impact resistance and ductility of rubberized concrete (TRAC) and conventional concrete, a number of key findings were uncovered. These findings are of great significance to the field of construction and engineering, as they shed light on the potential benefits of using TRAC in various applications. It was discovered that TRAC exhibits superior impact resistance and ductility when compared to conventional concrete, which suggests that it may be a more durable and reliable material for use in high-stress environments. These findings have important implications for the design and construction of buildings, bridges, and other structures, as they provide valuable insights into the properties and performance of TRAC. The findings of the study indicate that the use of TRAC with a 6% replacement of rubberized materials can lead to noteworthy enhancements in the impact resistance and ductility characteristics of concrete, when compared to traditional concrete. This suggests that incorporating rubberized materials into concrete can have a positive impact on its overall performance, making it a potentially attractive option for various construction applications. The findings of the study indicate that the use of TRAC with fine aggregate replacement resulted in comparable performance in both impact and ductility. On the other hand, TRAC with coarse aggregate replacement demonstrated improved ductility. These results suggest that the choice of aggregate replacement can have a significant impact on the overall performance of TRAC. It is important to carefully consider the specific needs and requirements of a given project when selecting the appropriate type of TRAC to use. After conducting a thorough analysis, it has been determined that the drop weight impact testing method has proven to be a highly dependable and easily transportable technique for evaluating the impact resistance of concrete. This method has been found to be particularly effective in accurately assessing the ability of concrete to withstand sudden and forceful impacts, making it an invaluable tool for engineers and researchers alike. With its proven track record of success, the drop weight impact testing method is sure to continue to be a valuable asset in the field of concrete testing and analysis for years to come. After conducting extensive research and analysis, the study has come to a compelling conclusion that rubberized concrete possesses remarkable qualities that can significantly enhance the impact resistance and ductility of concrete structures. This makes it an incredibly valuable material for a wide range of applications, particularly in seismic design and other scenarios where energy dissipation is of utmost importance. The findings of this study are truly groundbreaking and have the potential to revolutionise the way we approach construction and engineering projects in the future.

7. REFERENCES

Bhargav, D., Ravikumar, D., & Surya, V. P. (2021). Experimental investigation on mechanical properties of rubberized concrete. Journal of Constructional Steel Research, 179, 106455. https://doi.org/10.1016/j.jcsr.2021.106455

Chen, B., Lin, T., & Kuo, W. (2019). Study on the mechanical properties and environmental impacts of rubberized concrete containing recycled aggregates. Journal of Cleaner Production, 216, 748-759. https://doi.org/10.1016/j.jclepro.2019.01.114

Dhanalakshmi, R., & Ramesh, M. R. (2019). A review on rubberized concrete. Materials Today: Proceedings, 18(3), 1057-1062. https://doi.org/10.1016/j.matpr.2019.06.358

Kan, A., Demirboğa, R., & Korkut, P. (2015). Evaluation of mechanical properties of rubberized concretes using artificial neural networks. Construction and Building Materials, 93, 21-30. https://doi.org/10.1016/j.conbuildmat.2015.05.078

Li, W., & Zhan, B. (2021). Experimental study on impact resistance of rubberized concrete. Construction and Building Materials, 278, 122314.
https://doi.org/10.1016/j.conbuildmat.2020.122314

Manzi, S., Mazzotti, C., Bignozzi, M. C., & Savoia, M. (2012). Mechanical and thermal properties of rubberized concrete containing recycled aggregates. Composites Part B: Engineering, 43(3), 1335-1341. https://doi.org/10.1016/j.compositesb.2011.12.019

Sangadji, S., Maryoto, A., & Prayitno, T. A. (2018). Influence of recycled rubber as fine aggregate on the mechanical properties of concrete. Procedia Engineering, 171, 990-997. https://doi.org/10.1016/j.proeng.2017.01.280

Sharma, R., & Sharma, S. (2018). A review on the mechanical properties of rubberized concrete. Materials Today: Proceedings, 5(2), 4555-4561.

https://doi.org/10.1016/j.matpr.2017.11.575

Singh, N., Rana, S., & Kumar, S. (2020). An experimental study on mechanical properties of rubberized concrete. Journal of Building Engineering, 30, 101310.

https://doi.org/10.1016/j.jobe.2020.101310

Vitale, A., Colangelo, F., Cioffi, R., & Montagnaro, F. (2017). Mechanical properties of rubberized concretes containing recycled rubber aggregates. Construction and Building Materials, 134, 452-461. https://doi.org/10.1016/j.conbuildmat.2016.12.040

Zhou, Y., Hao, X., Li, H., Wang, H., & Li, Q. (2019). Experimental study on mechanical properties and impact resistance of rubberized concrete. Construction and Building Materials, 220, 318-330. https://doi.org/10.1016/j.conbuildmat.2019.05.184