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ORIGINAL ARTICLE

Effect of combined drink cans and steel fibers on the impact resistance and mechanical properties of concrete

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ABSTRACT – This study investigated the combine effect of 0.2 % drink cans and steel fibers with volume fractions of 0%, 0.5%, 1%, 1.5%, 2%, 2.5% and 3% to the mechanical properties and impact resistance of concrete. Hooked-end steel fiber with 30 mm and 0.75 mm length and diameter, respectively was selected for this study. The drinks cans fiber were twisted manually in order to increase friction between fiber and concrete. The results of the experiment showed that the combination of steel fibers and drink cans fibers improved the strength performance of concrete, especially the compressive strength, flexural strength and indirect tensile strength. The results of the experiment showed that the combination of steel fibers and drink cans fibers improved the compressive strength, flexural strength and indirect tensile strength by 2.3, 7, and 2 times as compare to batch 1, respectively. Moreover, the impact resistance of fiber reinforced concrete has increase by 7 times as compared to non-fiber concretes. Moreover, the impact resistance of fiber reinforced concrete consistently gave better results as compared to non-fiber concretes. The fiber reinforced concrete turned more ductile as the dosage of fibers was increased and ductility started to decrease slightly after optimum fiber dosage was reached. It was found that concrete with combination of 2% steel and 0.2% drink cans fibers showed the highest compressive, split tensile, flexural as well as impact strength.

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impact resistance.

INTRODUCTION

Nowadays, abundant of high-rise buildings made of reinforced concrete are displayed in most countries. Most countries perform beautiful architectural design that involved the production of reinforced concrete as main canvas. Normal reinforced concrete products usually ended up with more defects as year's progress and led to researcher's deduction that use of fibers are necessary to enhance its strength [1]. Furthermore, the reduction of wastes at the streets can be applied by thoroughly changing it into fibers for constructions hence create a cleaner environment for the country surroundings [2–5]. In the research, steel fibers and drink cans fibers are used in adequate dosage to produce fiber reinforced concrete (FRC). Steel fibers and drink can fibers are efficient fiber materials made up from steel, tin and aluminum that set with high tensile when implemented inside reinforced concrete. Most modern civil constructions demand the usage of fiber inside reinforced concrete as severely visible defects can be prevented on modern structures. Normal concrete has low tensile strength and strain capability which makes it physically brittle especially in terms of impact resistance.

The purpose of fiber reinforced concrete production is to enhance the structure as compared to normal reinforced concrete. The steel fibers and drink cans fibers commonly distributed inside the reinforced concrete strengthened the bonding of aggregates which led to higher ductility and reduction of cracks on the structure caused by any forces [6]. Therefore, reduction on maintenance and cost of repair are achieved because of the low cost and high performance of the steel fibers and drink cans fiber reinforced concrete under harsh climate conditions and in marine environments. Other than that, it is found that silica fume, due to high pozzolanic activity, is an essential material when producing fiber reinforced concrete; however, it also causes the concrete to have a slightly brittle structure [7–12]. Nia et al. [10] has used 0.2%, 0.3% and 0.5% of polypropylene fiber and 0.5 % to 1 % steel fiber to increase impact strength of concrete. They found that the highest impact strength was produced by inclusion of 1% steel fiber. Therefore, enhancement on ductility of concrete is a significant goal in concrete science and must be reconsidered by researchers. All engineering properties such as flexural strength, impact resistance, fracture toughness and fatigue loading can also be enhanced in concrete after the inclusion of fibers [13–16].

Concrete is also a strain-stress sensitive material which can be specified when high stress-strain behavior is observed as concrete is under short duration dynamic loads compared to it under static loads. The resistance of concrete under dynamic loadings can be evaluated through various types of test procedures such as the drop-weight, explosive test, test, constant strain rate test, and projectile impact test. However, the drop-weight test is the simplest, as reported by the ACI Committee 544 [17–19]. However, none of study been conducted by combining drink cans and steel fibre to reinforced concrete. Therefore, in the present work, fibrous and non-fibrous concrete specimens with addition drink cans and steel fibres under impact and mechanical loads were experimentally assessed.

METHODS AND MATERIALS

Ordinary Portland cement and silica fume were used in the experimental work. The cement and silica fume were mix together before performing the concrete mix. Coarse aggregates 14mm in size and fine aggregates with a 2.6 fineness modulus were used in the experiment. Other than that, hooked-end steel fibers with a length of 30mm and diameter (d) of 0.75mm or aspect ratio (l/d) of 40 and drink can fibers with a length (l) 30mm and diameter (d) of 10mm were twisted manually and were prepared in the experimental study. The geometry of the steel fibers and drink cans fibers were shown in Figure 1 and Figure 2, respectively. The steel fibers proportions were taken as appropriate percentage of 0%, 0.5%, 1%, 1.5%, 2%, 2.5% and 3% combined with a constant of 0.2% drink cans fiber volume fraction. The steel fibers were boiled inside a bucket at 100°C for 5 minutes to loosen the glue among the fibers. Then, the mix proportions were designed by trial and error. Consequently, the fine aggregate was mixed first for 1 minute and coarse aggregate were added for another 1 minute.

Cement mixed with silica fume was poured into the mix machine and water was included afterwards. The silica fume dosage used for each fiber reinforced concrete mix proportion was adjusted according to the quantity of cement to cover gaps in the process of mixture and to achieve a true slump [20]. The concrete was mixed for 2 minutes. Finally, the steel fibers and drink cans fibers were added to the mixture and mixed for 5 minutes. The mix proportion was designed to distribute the fibers evenly inside the structure as given in Table 1.

Figure 1. Steel fibers.

Figure 2. Drink cans fibers.

Table 1. Mix proportions of concrete.

Batch	W/(C+Sf)	Cement (kg/m³)	Silica fume (kg/m³)	Fine agg. (kg/m³)	Coarse agg. (kg/m³)	Water (kg/m³)	Steel fiber (%)	Drink cans fiber (%)
1	0.46	385	11.52	920	884	177	-	0.2
2	0.46	385	11.52	920	884	177	0.5	0.2
3	0.46	385	11.52	920	884	177	1.0	0.2
4	0.46	385	11.52	920	884	177	1.5	0.2
5	0.46	385	11.52	920	884	177	2.0	0.2
6	0.46	385	11.52	920	884	177	2.5	0.2
7	0.46	385	11.52	920	884	177	3.0	0.2

In the research, a series of concrete mixture with water-cement ratio of 0.46 were prepared in the laboratory. The fiber volume fraction (Vf) 0%, 0.5%, 1%, 1.5%, 2%, 2.5% and 3% of steel fiber were combined with 0.2% of drink cans fiber in the mixes. The mechanical properties test on compressive strength (BS EN 12390-3; 2002), splitting tensile (BS EN 12390-6:2009) and flexural strength (BS EN 12390-5:2009) test were performed on 100 mm cube, 150 mm x 300 mm height cylinder and 100 mm x 100 mm x 500 mm prism, respectively. The compressive strength tests were performed at age of 7, 28, and 56 days on 63 concrete cube, the flexural strength tests were performed at age 28 days on 21 prims samples and splitting tensile strength tests were performed at 28 and 56 days on 42 concrete cylinder samples. Impact tests to determine the impact strength were performed at age 7 and 28 days in accordance with ACI Committee 544 on 21 concrete slab samples.

The slab specimens were put on four supports and clamped to prevent its movement and the height of the drop weight is set at 500-mm from ground surface as shown in Figure 3. Then, the 1.3 kg steel ball was set to fall freely onto the slab specimen surface numerous times and the number of blows until service and ultimate crack observed were recorded in a table. The set up of the height of drop weight were originated and upgraded to desired height as referred from Zakaria et al. [21, 22] method of low impact drop test. The service crack means the first crack which appeared on the concrete due to impact, while ultimate crack when the concrete slab completely separated.

Figure 3. Impact resistance setup.

Impact energy (E) is calculated by using Eq. (1). N_1 denoted the number of blows required for first and failure crack, m is mass of steel ball (kg), g is acceleration of gravity m/s^2 and h is the drop height of steel ball.

$$E = N_1 mgh \tag{1}$$

RESULTS

Experimental Testing

Compressive, flexural and splitting tensile strength of cubes, prims, and concrete cylinders were presented in Table 2 and graphically illustrated as shown in Figure 4 to Figure 6.

Table 2. Mechanical properties result of specimens.

Batch	Compressive st. (MPa)			Flexural st. (MPa)	Splitting tensile st. (MPa)	
Days	7	28	56	28	28	56
1	7	26.24	48	5.29	2.00	2.20
2	8.1	32.5	59.6	5.48	2.09	2.67
3	17.5	33.8	61.1	5.80	3.73	4.20
4	22.5	28.7	62.7	6.30	3.45	5.44
5	37.9	59.3	64	6.98	3.97	5.71
6	11.3	30.3	45	3.42	3.43	4.82
7	11.7	32.0	42	3.21	3.45	4.52

Compressive Strength

Figure 4 showed the results of compressive strength for all specimens. Targeted compressive strength of concrete for this research is 25 MPa at age 28 days, however the compressive strength of concrete as shown in Table 2 is higher than the targeted strength, and this is maybe due to the inclusion of drink cans fiber in the mixtures. Generally, the results obtained suggest that the higher the steel fiber proportion in the mixtures, the higher the compressive strength gained. However, the strength started to decrease slightly after it reached optimum fiber volume fraction (Vf). An increase in compressive strength, up to 33% can be observed in batch 5 which are containing 2% steel and 0.2 % drink cans fiber as compared to control sample in batch 1.

The previous research conducted by M. Nili et al. [7] shows that the inclusion of 0.5 % fiber has increase the compressive strength at age 28 days by 12% which are lower as compared to the current research increase the strength by 23.8 %. It is maybe due to the inclusion of 0.2 % of drink can fibers and 0.5% steel fiber has increased the strength of concrete as compared to the inclusion 0.5 % steel fiber only.

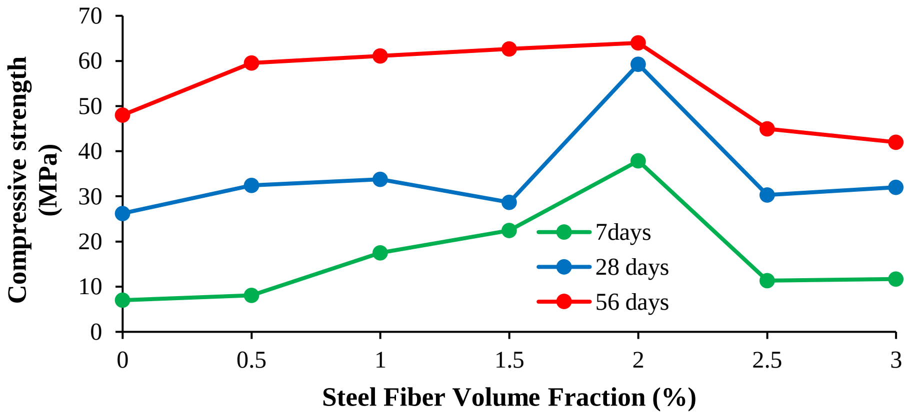

Figure 4. Compressive strength of concrete.

Flexural Strength

Three numbers of beams specimens containing steel fiber and drink cans fiber dosage for all bathes were tested. Figure 5 showed the average flexural strength obtained after 28 days of curing. The inclusion of steel and drink cans fiber has increased the flexural strength of prims by 32 % as compared to the control sample. Batch 1, 2, 3, 4, and 5 has an increase in flexural strength of 5.29, 5.48, 5.8, 6.3, and 6.98 MPa respectively whereas batch 6 and 7 has a flexural strength of only 6.30 and 3.42MPa which was very less compared to all the other five samples. The reason may be due to the excessive percentage of steel fibers in the mix which was 2.5% and 3%. The 3% fiber dosage of steel fiber has created lot of voids in the beam which led to lower flexural strength.

Batch 5 has the maximum flexural strength of 6.98MPa which contained 2% and 0.2% of steel fiber and drink cans fiber, respectively. It is concluded that the batch 5 was the best combination of steel and drink cans fibers in the concrete mix. The previous research conducted by M. Nili et al. [7] shows that the inclusion of 0.5 % fiber has flexural strength of 6.24 MPa at age 28 days which are higher as compared to the current research produced 5.48 MPa. It is maybe due to the inclusion of 0.2 % of drink can fibers and 0.5% steel fiber has reduced the flexural strength of concrete slightly as compared to the inclusion 0.5 % steel fiber only. However, the results showed better performance as compared to batch 1 without the presence of steel fiber.

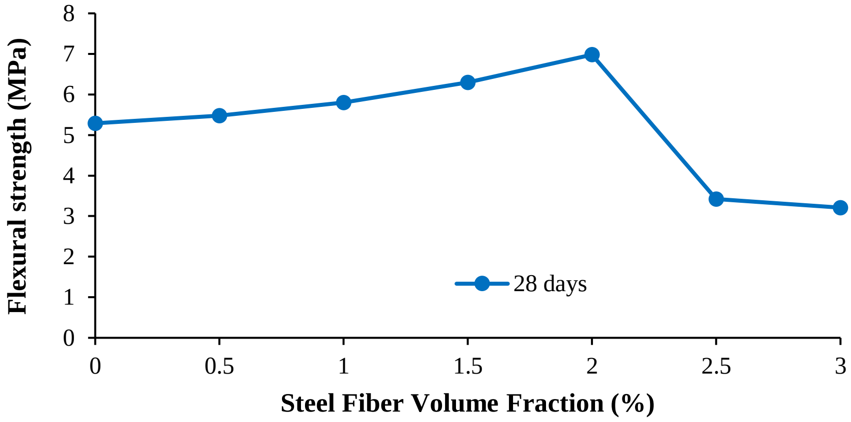

Figure 5. Flexural strength of prism at 28 days.

Splitting Tensile Strength

The splitting tensile strength of cylinder fiber reinforced concrete specimens are tested in the laboratory. The splitting tensile strength was also affected by inclusion of combination of steel and drink cans fibers in the cylinder by increasing the strength at 28 days by 98% and 160% at 56 days as compared to the control sample as shown in Figure 6. The optimum results of indirect tensile strength of the specimens with fiber content differ from compressive and flexural strength results. The control sample at batch 1 have a low splitting tensile compared to other batches which was 11.73 MPa because silica fume turned the sample to become more brittle that normal reinforced concrete which is in line with M. Nili et al. [7]. However, the addition of fibers dosage in batch 2 to batch 7 specimens increased the results magnificently as the fiber bridging the initial crack resulting on the increment of splitting tensile strength. The improvement of tensile properties of the specimen were relevant as stated by M. N. A. Nordin [23], as fibers help in resist the high load and increased bonding between the concrete and the fiber matrix. Batch 1, 2, 3, 4 and 5 at 28 days increased in tensile strength of 2, 2.09, 3.73, 3.45, and 3.97 MPa respectively whereas batch 6 and 7 has a tensile strength of 3.43, and 3.45 MPa which was a big decrement from the previous five batches. The indirect tensile strength at 56 days displayed slightly higher results from 28 days specimens were due to the presence of silica fume in the concrete mix. From the result, the increase of splitting tensile strength results from batch 1 to batch 5 and decrease of the results from batch 6 to batch 7 is highly influenced by the content of fibers implemented in the specimen. The amount 2% of steel fibers combined with 0.2% constant drink cans fiber seemed to be the optimum amount of fibers for cylinder specimens. This is maybe due to the presence of silica fume that increasing the concrete strength after 28 days.

The previous research conducted by M. Nili et al. [7] shows that the inclusion of 0.5 % fiber has flexural strength of 3.84 MPa at age 28 days which are higher as compared to the current research produced 2.09 MPa. It is maybe due to the inclusion of 0.2 % of drink can fibers and 0.5% steel fiber has reduced the splitting tensile strength of concrete slightly as compared to the inclusion 0.5 % steel fiber only. However, the result showed better performance as compared to batch 1 without the presence of steel fiber.

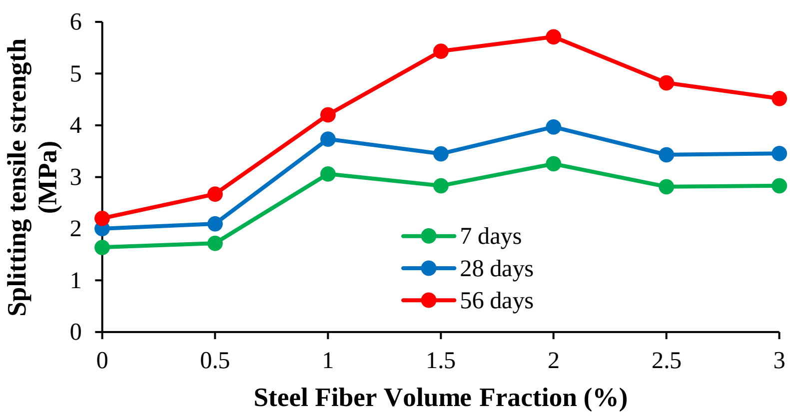

Figure 6. Splitting tensile strength.

Impact Resistance

Table 3 showed the number of blows required for first and failure crack of concrete slab. Number of blows for 7 and 28 days for first (N1) and failure (N2) crack were in this table. The different between these two values (N2-N1) showed the effectiveness of fiber to bridge the gap due to the first crack until failure occurred. Batch 5 showed the highest number of blows at failure of 163 blows as compared to the others. The value of (N2-N1) for the batch that was 29 also was the highest as compared to others.

Table 3. Impact resistance of concrete slab.

Batch no.	Steel fibre	Number of blows (N) at 7 days		N2-N1 at 7 days	Number of blows (N) at 28 days		N2-N1 at 28 days
		First Crack (N1)	Failure Crack (N2)		First Crack (N1)	Failure Crack (N2)	
1	0	16	19	3	19	24	5
2	0.5	32	47	15	40	54	14
3	1	58	70	12	75	94	19
4	1.5	87	105	18	105	115	11
5	2	114	139	25	134	163	29
6	2.5	110	134	24	133	160	27
7	3	107	130	23	124	150	26

As shown in Figure 7 the number of blows subjected to concrete slab has increased regularly according to the percentages of the steel fibers and drink cans fibers presence inside the concrete slab samples. The highest data obtained from the impact resistance was when the samples have 2% steel fibers and 0.2% drink cans fibers presence in it. The samples also gradually decreased when the sample contained 2.5% and 3% steel fibers which stated that too much amount of steel fibers weakened the samples strength as the quantity of fiber was too much and didn't bond properly with other materials in the concrete mix. In batch 5, the data for 7 days service and ultimate crack was 114 and 139 number of blows while the data for 28 days service and ultimate crack was 134 and 163 number of blows as shown in Figure 6.

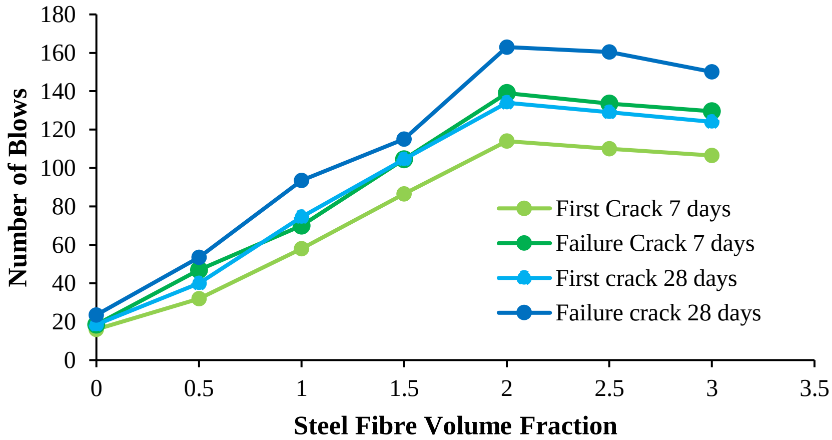

Figure 7. Number of blows for first and failure crack.

DISCUSSION

Impact Energy

The concrete can withstand most impact due to the samples have appropriate amount of fiber inside the concrete slabs. Some samples with percentage of 2.5% and 3% steel fibers appeared to have honeycombs on the surface of slabs. It resulted in slightly decreased on strength of the concrete. Figure 8 showed the impact energy that can be withstand by the concrete slab. It was accordance to Bagus et. Al [24], the greater the fiber volume fraction, the greater the impact absorption energy of the composite will be increased. Other that that, it was stated by Zakaria et. al. [25], [26], that considerable increase in crack resistance was due to the amount of fiber increased as compared with the control specimen. Maximum impact energy that can be absorbed by the slab is 1039kN mm for batch 5 at 28 days, followed by batch 6 and

7. This was due to the good combination between 0.2% drink cans fiber with 2% steel fiber that bridged the initial crack until crack failure appeared. This might be due to the friction between hooked-end steel fiber as well as twisted drink cans fiber with concrete that increased the impact resistance significantly as compared to other batches.

Crack pattern of batch 1 and batch 2 can be observed in Figure 9 and Figure 10, respectively. From the figure, it can be observed that different crack pattern, where in batch 1 with absence of steel fiber showed a straight line due to less effect of 0.2% drink cans fiber to bridge the crack as well as to distribute the stress to the other directions. Contradict with batch 2, the crack pattern on the slab showed two directions. The presence of steel fiber in the sample distributed the stress to the directions while absorbing the impact energy. Therefore, the combination of steel and 0.2% drink cans fiber can be used to construct column for the highway bridge and column at parking area that sometime can be hit by vehicles.

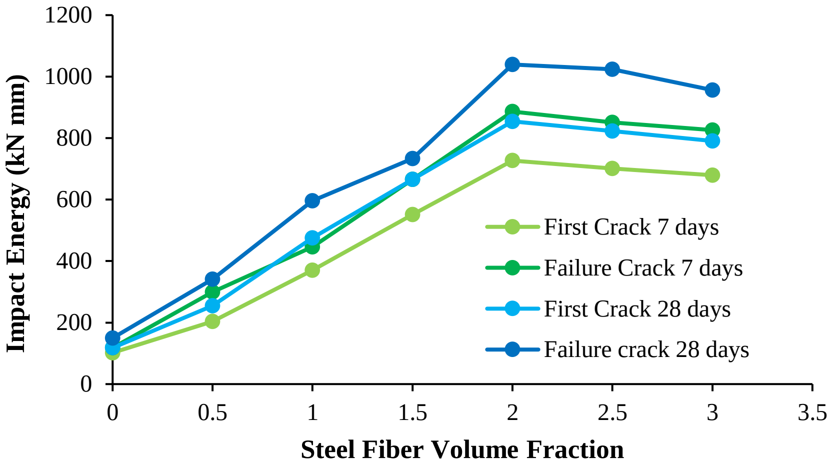

Figure 8. Impact energy of concrete slab.

Figure 9. Crack pattern for batch 1.

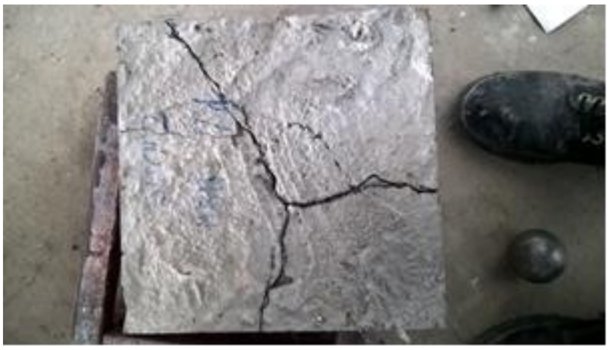

Figure 10. Crack pattern for batch 2.

CONCLUSIONS

The impact resistance of reinforced concrete slabs with varied amount of steel fibers and drink cans were successfully conducted. The results are summarized below:

1) The inclusion of steel fiber and drink cans fiber into the mixtures generally improves the compressive strength. The strength of specimens with 2% steel fiber and 0.2% drink cans fibers at 56 days was increased by 33.3% as compared to control sample (batch 1).
2) The maximum flexural strength results obtained at age 28 days for prims that contained 2% of steel fiber and 0.2% drink cans fiber. The flexural strength was increased by 32 % as compared to control sample.
3) The splitting tensile strength was also affected by inclusion of combination of steel and drink cans fibers in the cylinder by increasing the strength at 28 days by 98% and 160% at 56 days as compared to the control sample. This is maybe due to the presence of silica fume that increasing the concrete strength after 28 days.
4) The addition steel and drink cans fibers improve the specimens' [N2-N1] values at 7 and 28 days by 7 and 5.4 times, respectively.
5) The presence of steel fiber in concrete slab will affect the crack pattern of concrete due to the bridging effect of fiber after first crack appear on the concrete slab.
6) In general, concrete with 2% steel fiber and 0.2% drink cans fibers showed the best mechanical as well impact strength as compared to the other batches.

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REFERENCES

[1] K. Ravinder, "Strength Characteristics of Coca-Cola Tin Waste As Fibres in Concrete," *Int. J. Adv. Res. Found.*, vol. 3, no. 2, pp. 9–12, 2016.

[2] M. Batayneh, I. Marie, and I. Asi, "Use of selected waste materials in concrete mixes," *Waste Manag.*, vol. 27, no. 12, pp. 1870–1876, 2007.

[3] A. Alavi Nia, M. Hedayatian, M. Nili, and V. A. Sabet, "An experimental and numerical study on how steel and polypropylene fibers affect the impact resistance in fiber-reinforced concrete," *Int. J. Impact Eng.*, vol. 46, pp. 62–73, 2012.

[4] M. Leone, G. Centonze, D. Colonna, F. Micelli, and M. A. Aiello, "Fiber-reinforced concrete with low content of recycled steel fiber: Shear behaviour," *Constr. Build. Mater.*, vol. 161, pp. 141–155, 2018.

[5] J. Y. Lee, H. O. Shin, D. Y. Yoo, and Y. S. Yoon, "Structural response of steel-fiber-reinforced concrete beams under various loading rates," *Eng. Struct.*, vol. 156, no. August 2017, pp. 271–283, 2018.

[6] H. Ueno, M. Beppu, and A. Ogawa, "A method for evaluating the local failure of short polypropylene fiber-reinforced concrete plates subjected to high-velocity impact with a steel projectile," *Int. J. Impact Eng.*, vol. 105, pp. 68–79, 2017.

[7] M. A. A. BIN ABDULLAH and Report, "Soft Drink Cans Clipping As Fiber Reinforcement in Concrete Mix," no. June, 2014.

[8] M. Khan, M. Cao, and M. Ali, "Effect of basalt fibers on mechanical properties of calcium carbonate whisker-steel fiber reinforced concrete," *Constr. Build. Mater.*, vol. 192, pp. 742–753, 2018.

[9] W. Zhang, S. Chen, and Y. Liu, "Effect of weight and drop height of hammer on the flexural impact performance of fiber-reinforced concrete," *Constr. Build. Mater.*, vol. 140, pp. 31–35, 2017.

[10] L. Jin, R. Zhang, G. Dou, and X. Du, "Fire resistance of steel fiber reinforced concrete beams after low-velocity impact loading," *Fire Saf. J.*, vol. 98, no. February, pp. 24–37, 2018.

[11] M. Mastali, A. Dalvand, A. R. Sattarifard, and M. Illikainen, "Development of eco-efficient and cost-effective reinforced self-consolidation concretes with hybrid industrial/recycled steel fibers," *Constr. Build. Mater.*, vol. 166, pp. 214–226, 2018.

[12] W. Abbass, M. I. Khan, and S. Mourad, "Evaluation of mechanical properties of steel fiber reinforced concrete with different strengths of concrete," *Constr. Build. Mater.*, vol. 168, pp. 556–569, 2018.

[13] K. H. Mo, K. K. Q. Yap, U. J. Alengaram, and M. Z. Jumaat, "The effect of steel fibres on the enhancement of flexural and compressive toughness and fracture characteristics of oil palm shell concrete," *Constr. Build. Mater.*, vol. 55, pp. 20–28, 2014.

[14] M. Mastali and A. Dalvand, "Use of silica fume and recycled steel fibers in self-compacting concrete (SCC)," *Constr. Build. Mater.*, vol. 125, pp. 196–209, 2016.

[15] M. Nili and V. Afroughsabet, "Combined effect of silica fume and steel fibers on the impact resistance and mechanical properties of concrete," *Int. J. Impact Eng.*, vol. 37, no. 8, pp. 879–886, 2010.

[16] U. Iqbal, M. A. Akhund, and A. Saand, "Soft Drink Tins as Fibre Reinforcement in Concrete," no. December, pp. 14–15, 2015.

[17] D. Mazlan, "Utilisation of soft drink can as fibre reinforcement in concrete," no. July, pp. 15–20, 2011.

[18] L. Soufeiani, S. N. Raman, M. Z. Bin Jumaat, U. J. Alengaram, G. Ghadyani, and P. Mendis, "Influences of the volume fraction and shape of steel fibers on fiber-reinforced concrete subjected to dynamic loading – A review," *Eng. Struct.*, vol. 124, pp. 405–417, 2016.

[19] N. Banthia, S. Mindess, and J. F. Trottier, "Impact resistance of steel fiber reinforced concrete," *ACI Mater. J.*, vol. 93, no. 5, pp. 472–479, 1996.

[20] C. Wee Kang, C. Chee Ban, O. Chuan Wei, P. W. Ken, and L. K. Heng, "The properties of slag-silica fume ternary blended mortar with quarry dust," *J. Mech. Eng. Sci.*, vol. 14, no. 1, pp. 6443–6451, 2020.

[21] Z. C. Muda *et al.*, "Impact Resistance Behaviour of Banana Fiber Reinforced Slabs," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 32, no. 1, 2016.

[22] Z. C. Muda *et al.*, "Impact Resistance Performance of Kenaf Fibre Reinforced Concrete," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 32, no. 1, pp. 0–4, 2016.

[23] M. N. A. Nordin *et al.*, "Tensile and impact properties of pulverized oil palm fiber reinforced polypropylene composites: A comparison study with wood fiber reinforced polypropylene composites," *J. Mech. Eng. Sci.*, vol. 12, no. 4, pp. 4191–4202, 2018.

[24] B. T. Mulyo and H. Yudiono, "Toughness analysis of pineapple leaves fiber composite as alternative material for SNI helmet," *J. Mech. Eng. Sci.*, vol. 13, no. 4, pp. 5961–5972, 2019.

[25] Z. C. Muda *et al.*, "Impact Resistance Behaviour of Light Weight Rice Husk Concrete with Bamboo Reinforcement," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 32, no. 1, 2016.

[26] F. Strength, O. F. Long, W. Cans, and R. C. Beam, "Social & Behavioural Sciences IEBMC 2017 8 th International Economics and Business Management Conference Flexural Strength of Long Waste Cans Fibers," pp. 0–5, 2018.