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Elastic cement Mechanical and dynamical properties

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ABSTRACT: *The motivation behind this paper is to cover an exploratory examination that investigates the impact of utilizing reused elastic powder as an other fine total in cement blends. Normal sand in the solid blends was somewhat supplanted by 5%, 10%, 15%, and 20%. Actual properties, for example, the thickness, the compressive strength, the new solid properties, the split-strain, and the effect load limit are inspected. The outcomes uncovered a diminishing in the compressive strength of solid chambers containing elastic. The unique presentation of the elastic cement is of high significance in light of its high strong nature, as the elastic particles that are remembered for the solid positively affect the powerful exhibition. The ends that were gotten from this examination ensnare potential applications where rubber treated cement can be efficiently utilized. Despite the fact that rubber treated solid combination for the most part has a diminished compressive strength that may restrict its utilization in certain underlying applications, it has various attractive properties, for example, lower thickness, higher durability, and higher effect obstruction contrasted with traditional cement.*
Keywords: *Rubberized concrete; Compressive strength;Splitting tensile strength; Impact load*

I. INTRODUCTION

Countries and cities have been faced with major increasing problems with the disposal of recycled materials,suchasrubber,glass,andplasticsforseveralyears.Theconsumptionoftheworld'srubberha snearlyr eached24.9milliontonsinyear2010.IntheU.S.alone,approximately3.9milliontonsofscraptiresareproduce deveryyear,outofwhich1.36milliontonsarerecycledand2.54milliontonsareburnedorland-filled.Inviewofthewideandvastmarketforscraptires,aboutaquarterofallscraptiresendupinlandfillsnumber ingtoapproximately27milliontiresorroughly6milliontonsannually, making-up over 12% of all solid waste. The disposal of the scrap tires materials become very costly once they are sent to landfills;nottomentionthewidespacethattheyuseinlandfillstodisposeof,andthehazardthattheycausetowar dstheenvironment.Basedonthisinformation,therubberuseinconcreteandpavementmaterialprovidesanenv ironmentally sustainablemethodfordisposingofthemillionsoftiresthatareannuallygenerated.

Powdered rubber is a general term or an expression given to recycled rubber that is generated from scraptires.Theproductionofpowderrubberconsistsofremovingthesteelandfluff,thenusingagranulatorand/ orcrackermill,withtheaid ofcryogenicsormechanicalmeans,inordertoreducethesizeofthetireparticles.

A well-known fact is that tires can be divided into two major groups: automobile tires and truck tires, and they are different from each other. The description of the rubber source is very important and shouldalwaysbespecifiedinthebecauseithasaninfluenceonthetextureandtheshape,andconsequently,onthe characteristicsoftheconcretethatisadjustedbytheadditionofthespecifiedpercentageoftherubber.Itisalsoim portanttopointoutthatautomobiletiresandtrucktiresvarynotonlyinshape,weightandsize,butaboveall,inthe ratioofthecomponentsofthebasemixture.

Researchershaveconsideredthreewidecategoriesofdiscardedtirerubberconcretemixdesign:

1 Chipped Rubber: This type of rubber has dimensions of about 25–30 mm and used to replace the coarse aggregates in concrete.
2 Crumb Rubber: The particles of rubber are highly irregular, varying between 3–10 mm, and are used to replace the fine aggregates.
3 PowderedRubber:Theparticlesoftherubberaresmallerthan1mmandconsistofthepowderformeddurin gthecrunch process,fallenfromthemachineryoftheplantthatishandlingthewasterubber.Thistypeofrubbercouldbe usedasfiller in concrete due to itssize.

Ontheotherhand,andforsomanyyears,materialresearchershaveattemptedtomakeconcreteaductilemat erial.It appears, however, that due to the brittle nature of concrete, the most direct and effective approach in creating damage tolerant concrete structures would be to embed intrinsic tensile ductility into concrete. If concrete behaves like steel in tension (highly ductile), while retaining all other advantages (e.g. high and extreme compressive strength), concrete structureswithenhancedserviceabilityandsafetycanbereadilyrealized.

This research attempts to provide a solution for this worst limitation of concrete, i.e. brittleness and verylowtensilestrength.Makingconcreteaductilematerialwouldalsoimprovetheimpactstrengthandtough nessoftheconcrete.Another issue would be to seek ways of making the concrete “green” or environmentally friendly through the choice of materials whileretainingthecoreadvantagesof theconcrete.Ductilityisaverydesirablestructuralpropertybecauseitallowsthestressredistributionandallow swarningsignsofimpendingfailure.Theductilebehaviorenablestheconcretematerialtohavethecapacitytod eformandsupportflexuralandtensileloadsevenafterinitialcracking.Onematerialthatissuggestedasapossibl ereplacementofmineralaggregatesisrubberfromusedtires.Thisresearchfocusesontheeffectofreplacingthe fine aggregates (sand) with powdered rubber. A significant difference between mineral aggregates and tire derived aggregates is that individual particles are much more deformable than those of sand, gravel, or rock. Anothersignificant difference is that the unit weight is much lower; therefore, tire derived aggregates can be considered as lightweight aggregates.

II. LITERATUREOVERVIEW

ItisestimatedthateachpersondiscardsonecartireperyearintheUSA.Withapopulationofover300millionpeo ple,itindicates that every year, there is a total of 300 million tires that need to be disposed of [1–3]. Severalinnovativewaysofusingthesetireshavebeendevelopedinthelastyears,andtheyincludetirederivedfu elforcementkilnsandboilers[1],andtirederivedaggregatesusedasrawmaterialsforcivilengineeringprojects [3].However,notalltiresareconsumedinthesebeneficial ways and the scrap tires that remain are disposed of in various legal and illegal means (disposal of tiresinun-permittedareas).Thewholedisposaloftiresisdifficulttolandfillbecausetirestendtofloatbacktothesurfacewit htime.Stockpilesofscraptiresresultinpublichealth,environmental,andaestheticproblems,inadditiontobei ngfirehazards[2].TheUSgovernmentandthroughtheEnvironmentalProtectionAgency(EPA),encourages morestudiesonmethodsofrecyclingtires,becauseofthisenvironmentalconcern[2].Theuseofcrumbrubbera sareplacementformineralaggregatesinconcreteresultedinavastbeneficialuseoftires[4,5].However,noneof thestudieshaveelucidatedinanydetailthebeneficialaspectsofcrumbrubberandthemechanismbywhichthep ropertiesofcrumbrubberreinforcedconcretedifferfromthetraditionalconcrete.Crumbrubbercanbealightw eightsubstituteformineralaggregatesasitsdensityislessthanhalfofthatofmineralaggregate.Mineralaggreg ateshaveaunitweightordensityrangingbetween1600and2080kg/m^3
while crumb rubber unit weight or density ranges between 640 and 720 kg/m^3[6].
The effect of adding two kinds of crumb rubber and chipped rubber were studied by Khatib and Bayomy[7].Theypreparedthreegroupsofconcretemixtures:ingroupA,crumbrubberwasusedtoreplacefine aggregate,whileingroupB,
chippedrubberwasusedtoreplacecoarseaggregate,andingroupC,bothtypesofrubberwereusedinequalvolu mes.All

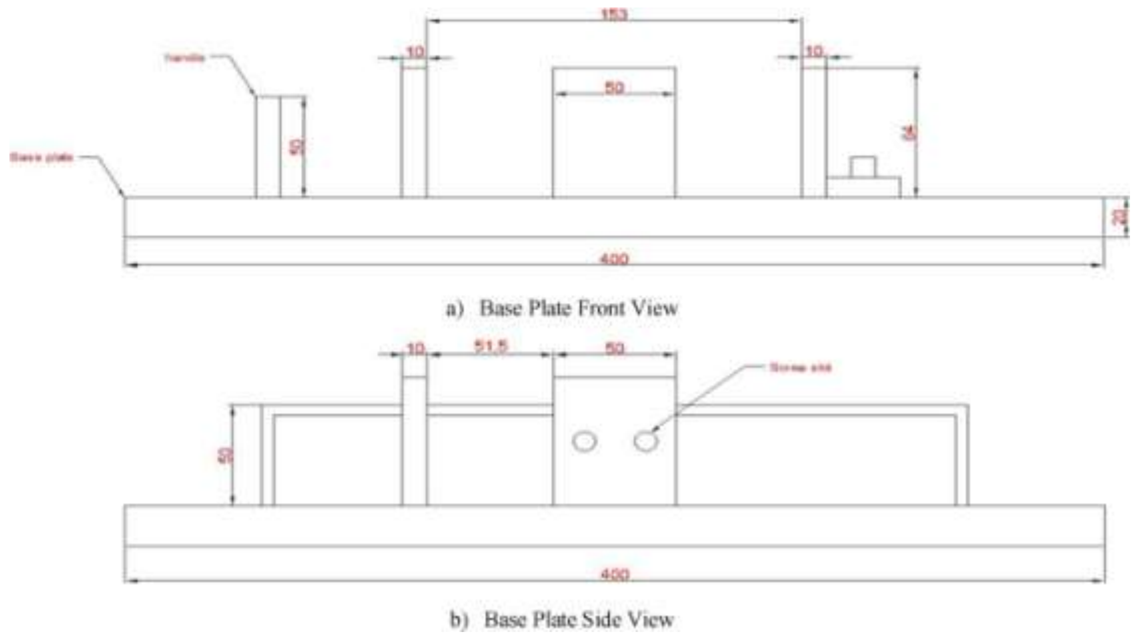

Fig. 1. Schematic of Impact Mechanism (Dimensions in mm).

of concrete more negatively than do only fine particles. Moreover, the plastic energy capacity of the normalconcretehasincreasedbyaddingrubber.Duetotheirhighplasticenergycapacities,concretehasshown

highstrains,particularlyunder the impacteffects.
Fattuhi and Clark [10] have proposed that rubberize concrete could possibly be utilized in the following applications:

1) Infoundationpadformachinery,andinrailwaystations,wherevibrationsdampingisneeded.
2) Intrenchfillingandpipebedding,pileheads,andpavingslabs.
3) Inrailwaybuffers,barriers,andbunkers,wheretheresistancetoimpactorblastisrequired.

Mostrecently,Guptaetal.[11,12]haveextensivelyexploredtheeffectoftheuseofacombinationofwasterubberandsilicafumeonthedurabilityandthemechanicalpropertiesoftheconcretemix.Theeffectofreplacementof fineaggregatesbywasterubberfiberswithacombinationsilicafumeasofreplacementofcement,ontheimpact resistanceofconcretehas also been assessed[13].
Themainpurposeofthisstudyconsistsofexploringthefeasibilityofincorporatingscraptiresinformofrubberpowder as fine aggregates in concrete mixes and to determine its effect on the mechanical properties of theconcretemix.Theparametersthatweremonitoredcomprisedtheinfluenceoftherubbercontentonthemechanicalpropertiesofrubberized

Fig**. 2.** The Fabricated Impact Mechanism.

concretestartingwiththe0%rubbercontent(norubber)andupto20%rubbercontent.Thehardenedconcreteproperties likethecompressivestrength,splittensilestrength,andimpactloadwerescrutinized.
Generally, several impact tests procedures have been employed to demonstrate the relative brittleness andimpactresistanceofconcreteandsimilarconstructionmaterials[1417].However,noneofthesetestsproceduresshasbeendeclaredastandardtest,atleastinpartduetothelackofstatisticaldataonthevariationoftheresults.Inthisregard,ACICommittee544[18]proposedadropweightimpacttesttoevaluatetheimpactresistanceoffiberconcrete.Thetestiswidelyusedsinceitissimpleandeconomical.Thus,thistestwasadoptedforthisstudytoinvestigaterubberconcrete.Accordingly,aspecialimpactmechanism(Fig.1)wasdesignedandfabricatedaccordingtoACI[18]recommendationsrelatingtotheadoptionofthedropweightimpacttesttechnique.Asummaryoftheimpacttestisthat,theconcretesamplesareplatedonthebottomofthemechanismwithathinlayerofpetroleumjellyoraheavygreaseandplacedonthebaseplatewithinthepositioninglugswiththefinishedfaceup(ifappropriate)asshowninFig.2.Thepositioningbracketisthenboltedinplace,andthehardenedsteelballisplacedontopofthespecimenwithinthebracket.Thedrophammerisplacedwithitsbaseuponthesteelballandheldtherewithjustenoughdownpressuretokeepitfrombouncingofftheballduringthetest. The base plate is withdrawn to a rigid base, such as a concrete floor or cast concrete block. The hammer is dropped repeatedly,andthenumberofblowsrequiredtocausethefirstvisiblecrackonthetopandtocauseultimatefailurearebothrecorded.Ultimatefailureisdefinedtobetheopeningofthecracksinthespecimenjustenoughforthepiecesofconcretetotouchthreeofthefourpositioninglugsonthebaseplate.Theresultsofthesetestsdisplayahigvariabilityandmayvary greatly with the different types ofmixtures.

III. EXPERIMENTALSETUP

In this experimental study, a total of 20 designated concrete mix designs containing 0, 5, 10, 15 and 20% of partial replacement of fine aggregates with powdered rubber were prepared. Ordinary Portland Cement(OPC)withaspecificgravityof3.15wasusedthroughoutthisstudy.Thesandusedintheexperimentwasobtainedfromalocalsourcewithawaterabsorptionrateof1%.Thecoarseaggregatethatwasutilizedintheexp erimentwascrushedangularstoneaggregateswithamaximumsizeof20mmhavingaspecificgravityof2.67wi thawaterabsorptionrateof0.5%.

The source of the rubber aggregate was recycled tires which were collected from a local tire recycling plant. The gradation of powdered rubber was determined based on the ASTM C136 Standard [19]. The term powdered rubber stands for recycled tire rubber with particle size less than 1 mm. A sieve analysis was performed on powdered rubber to fit the sand grain size distribution. The rubber was used without any surface treatment in order to investigate the effect of untreated tire particles on the mechanical properties of concrete. Drinking water with pH value of 7.0 was used in the concrete mix and the curing process of the concrete cylinders. The water was free of acids, organic matters, suspended solids, alkalis, andimpuritieswhichwhenpresent,mayhavesideeffectsonthestrengthofconcrete.Castingof100concretecylind ersof150mmby300mmwasconductedbasedonASTMC192[20].

Thecylinderswerecastedintothreelayersandeachlayerwastamped,usingasteelrod,movingallarou ndthelayertwentyfivetimes.Tampingofthenextlayerwasdonewithoutcrossingintothepreviouslayer.Thesu rfacewasfinishedbyrollingthetampingrodoverthesurfacetotrimtheconcrete.Theimpactresistanceofthespe cimenwasdeterminedbyusingthedropweightmethodof the Impact Test as recommended by the ACI committee 544 [18]. The size of the specimen recommended is 152 mm in diameterand63.5mminthicknessandtheweightofhammerdeployedis4.54Kgwithadropheightof457mm. Thecuringprocessinconcreteprohibitsthewaterintheconcretetodispersean dreducethehydrationofcement ortoreliefconcretefromanywaterloss.Inthecuringprocess,thecylindersmoldforthec oncretecylinderswere coveredwithplasticsheets(Fig.3)topreventtheevaporationofwater.Thenextday,theconcretecylinderswere removedfromthemoldandplacedinawatertankatacontrolledtemperaturefor28days.Eachspecimenwaslab eledwithorwithoutrubberand the date of themix.

IV. EXPERIMENTALPROCEDURE

Inthemixingprocess,theconcretewasdrymixedusingamechanicalmixer;afterwards,waterwasaddedgradu allyandmixedtillthehomogenousmixobtained.Powderedrubbersmixedwithcementandthenwithaggregat earefinallymixedwithwaterinordertoprohibitthelowspecificgravitypowderedrubbe rinitiallymixedwithag gregatefromfloatingtothetopofmixture.Thespecimensofstandardcylindersof150mmby300mmwereutiliz edtodeterminethecompressiveandsplittensilestrengthoftheconcretemix.However,cylindersof152mmby 63.5mmwereutilizedtodeterminetheimpactloadcapacity.Themixproportionsofdifferenttypesofpercenta gesofreplacementpercentageoffineaggregateswithpowderedrubber are summarized in Table1.

V. EXPERIMENTALRESULTS

Subsequently to when the concrete cylinders have acquired the 28 days strength, three types of experiments wereperformedtomeasurethecompressive,tensile,andimpactloadofthespecimens.Auniaxialcompressive loadtestingwasconductedaccordingtoASTMC39inordertomeasurethecompressivestrengthoftheconcret ecylinders[21].Priorto

Fig. 3. Cylinders Covered in Plastic Sheets for Curing.

testing,theareaofthe150mmdiameterby300mmheightcylinderswasmeasuredtobeincorporatedinthec omp utationconcretecompressivestrength.Thecylinderswerethenplacedintheuniversaltestingmachine,andacc ordingtoASTMC1231[22],thecylindersshouldbecappedwithneoprenepadcapstoprovideauniformloaddi stributionduringtheloadingprocess.Thecylinderswerethensubjectedtoasteadystressratevarying between0.2MPa/secto0.4MPa/sec.Oncethemaximumloadwasattained,theloadingprocessautomaticallystopped,andthevalueswererecorded.Consequently,breakpatternsweregeneratedduetothefailureofthecylindersthathaveproducedcracksinseveraldirections.Althoughconcreteisknowntobeweakinresistingdirecttension,itisimportanttomeasureitstensilestrengthduetothecrackingthathasdevelopedfromtheappliedloadingorotherkindsofeffects.Thesplit-cylindertestwasconductedforthe cylinder specimens, according to ASTM C496 [23] to determine the tensile strength of concrete since uniaxial tension is difficult to be conducted. Concrete cylinders 300 mm by 150 mm were placed horizontally between the platens of thecompressiontestingmachine(Fig.4).Thesteelstripswereplacedbetweenthehorizontalcylindersandtheplatensofthemachineinordertoprovideauniformdistributionoftheappliedloadandtolessenthestressesatthesurfaceofapplication,asshowninFig.5.Thecompressiveloadwasappliedandincreasedgraduallyalongthetotallengthofthecylinderuntilfailurehasoccurred.Thefailureoccurredalongtheverticaldiameterofcylinderwhichcausedittosplitintotwohalves,due totheindirecttensionstresses,asshowninFig.6.Therefore, the splitting tensile strength (f'_{ct}) of the specimen was calculated using the following equation:

$$f'_{ct} = \frac{2P}{\pi DL} \quad (1)$$

Table 1 Mixture proportions for concrete with waste tire replacing sand.

No.	Targeted f'c (M Pa)	Cement (Kg)	Water (Kg)	Gravel (Kg)	W/C	Sand (Kg)	Rubber (Kg)	Rubber (%)
1	30	31.68	16.32	87.49	55%	53.32	0	0%
2	(Mix 1)					50.65	2.67	5%
3						47.99	5.33	10%
4						35.08	8.00	15%
5						42.66	10.66	20%
6	35	34.84	16.37	87.5	50%	50.12	0	0%
7	(Mix 2)					47.61	2.51	5%
8						45.11	5.01	10%
9						42.6	7.52	15%
10						40.1	10.02	20%
11	40	38.71	16.43	87.49	45%	46.19	0	0%
12	(Mix 3)					43.88	2.31	5%
13						41.57	4.62	10%
14						39.26	6.93	15%
15						36.95	9.24	20%
16	50	43.55	16.51	87.5	40%	46.19	0	0%
17	(Mix 4)					39.21	2.06	5%
18						37.14	4.13	10%
19						35.08	6.19	15%
20						33.02	8.25	20%

Fig. 4. Cylinder Placed in the Steel Strips.

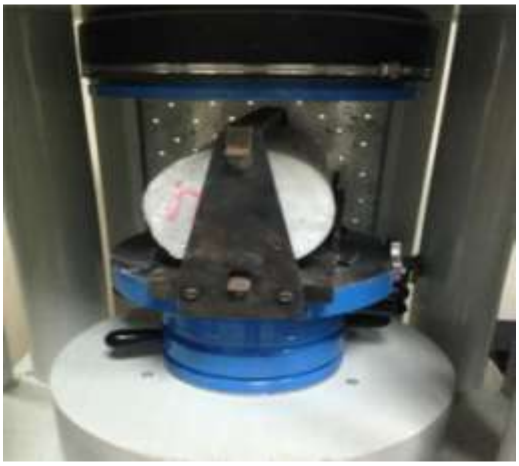

Fig. 5. Tensile Testing Machine.

Fig. 6. Tensile Testing.

Fig. 7. Rubberized Concrete Impact Failure.

Fig. 8. Plain Concrete Impact Failure.

Fig. 9. Portion of the Specimens Subsequently to Impact Load Failure.

Table 2 Conncrete cylinders compressive strength results.

Rubber (%)	MIX1 No.	f'c (MPa)	Avg. MPa	MIX2 No.	f'c (MPa)	Avg. MPa	MIX3 No.	f'c (MPa)	Avg. MPa	MIX4 No.	f'c (MPa)	Avg. MPa
0%	1	32.16 28.68	30.42	6	36.90 37.47	37.19	11	42.27 44.56	43.42	16	50.65 52.43	51.54
5%	2	15.41 16.88	16.15	7	27.46 26.3	26.88	12	32.40 33.73	30.07	17	40.09 39.8	39.95
10%	3	13.55 14.08	13.82	8	25.76 22.5	24.13	13	28.40 27.90	28.15	18	35.45 33.80	34.63
15%	4	12.55 11.20	11.88	9	20.36 18.70	19.53	14	22.58 21.67	22.13	19	25.28 22.63	23.96
20%	5	9.40 8.54	8.97	10	14.50 12.80	13.65	15	15.70 16.90	16.30	20	18.31 19.55	18.93

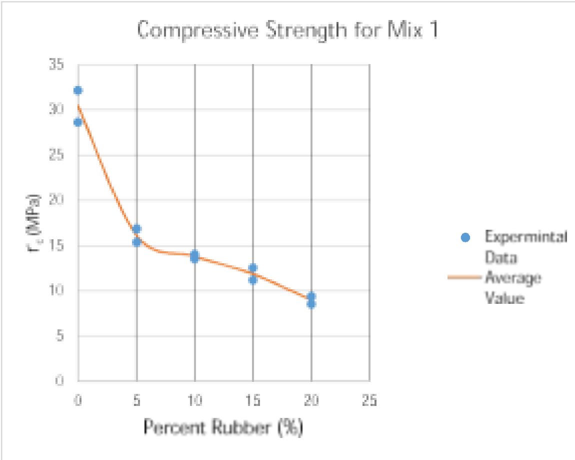

Fig. 10. Average Compressive Strength for Mix1.

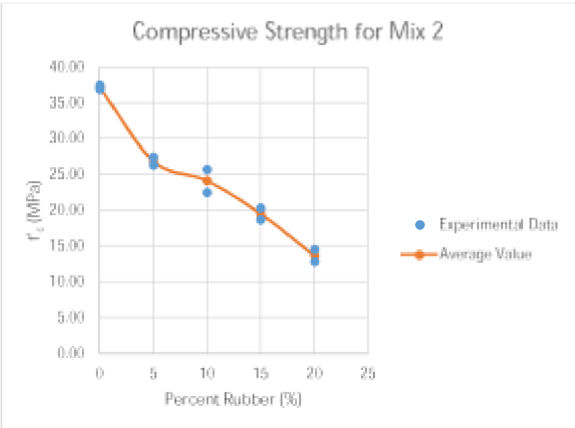

Fig. 11. Average Compressive Strength for Mix2.

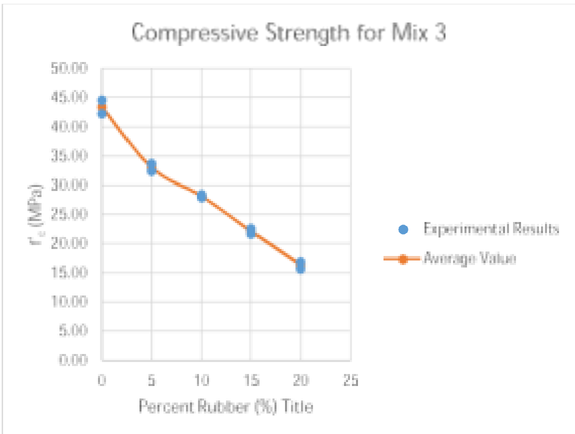

Fig. 12. Average Compressive Strength for Mix3.

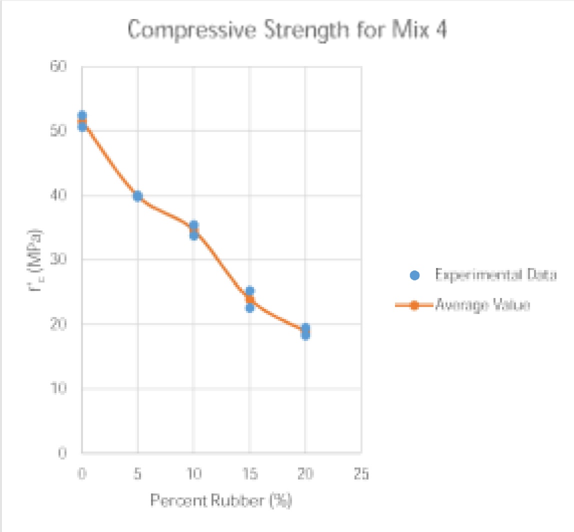

Fig. 13. Average Compressive Strength for Mix4.

Table 3 Splitting tensile strength (f'$_{ct}$) results.

Rubber (%)	MIX1 No.	f'ct (MPa)	Avg. MPa	MIX2 No.	f'ct (MPa)	Avg. MPa	MIX3 No.	f'ct (MPa)	Avg. MPa	MIX4 No.	f'ct (MPa)	Avg. MPa
0%	1	3.152 2.91	3.031	6	3.59 3.68	3.635	11	4.221 4.456	4.339	16	5.435 5.134	5.285
5%	2	2.433 2.55	2.492	7	2.73 2.62	2.675	12	3.541 3.244	3.393	17	4.307 4.166	4.327
10%	3	1.825 1.773	1.799	8	2.524 2.455	2.49	13	3.178 3.251	3.215	18	3.782 3.529	3.656
15%	4	1.755 1.822	1.789	9	2.234 2.356	2.295	14	2.883 2.791	2.837	19	3.173 2.856	3.015
20%	5	1.275 1.362	1.319	10	2.188 1.943	2.066	15	2.364 2.415	2.39	20	2.316 2.405	2.361

Fig. 14. Non-Rubberized Concrete Cylinders Splitting into Two Halves.

Where
P = load at failure (N)
L = length of the cylinder (mm) D = Diameter of the cylinder(mm)
Thesimplestoftheimpacttestsisthe“repeatedimpact”drop-weighttest.Thistestyieldsthenumberofimpactblows

deliveredbyadrophammerthatisaccumulateduntilthefirstvisiblecrackoccursanduntilthetestspecimenisfor cedto separatebycontinuedimpacting.Thisnumberoffersaqualitativeestimateoftheenergyabsorbedbythespeci menatthe

Fig. 15. Rubberized Concrete Cylinders without Splitting After Failure.

Table 4 ACI drop weight impact test results.

Rubber (%)	MIX1 No.	N Blows	Energy NM	MIX2 No.	N Blows	Energy NM	MIX3 No.	N Blows	Energy NM	MIX4 No.	N Blows	Energy NM
0%	1	59	1190	6	77	1553.42	11	93	1876.2	16	27	544.71
5%	2	36	726.27	7	50	1008.71	12	60	1210.46	17	112	2259.52
10%	3	29	585.05	8	40	806.979	13	49	988.54	18	73	1472.72
15%	4	23	464	9	33	665.75	14	38	766.62	19	61	1230.63
20%	5	18	363.13	10	25	504.36	15	31	625.4	20	43	867.49

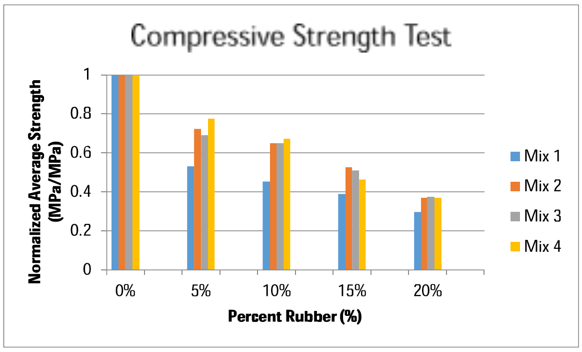

Fig. **16.** Normalized Concrete Compressive Strength with Plain Concrete Mix.

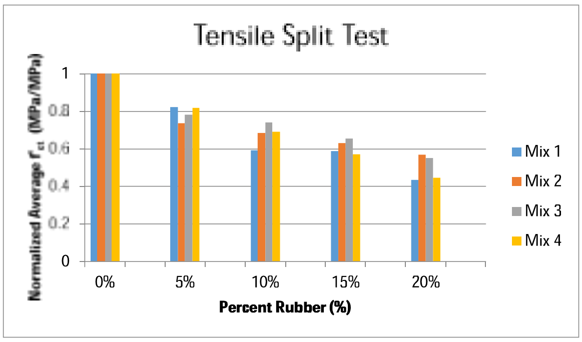

Fig. 17. Normalized Concrete Tensile Strength with Plain Concrete Mix.

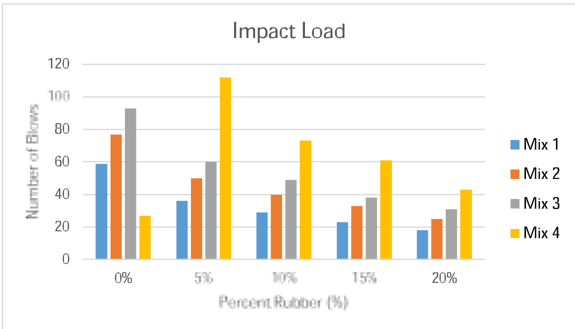

Fig. 18. Impact Load Blows as a Function of Rubber Replacement.

levels of the specified distress level (Figs. 7–9). The impact energy (IE) exposed to by the specimen is calculated using the following equation:

IE¼Nmgh ð2Þ

Where:

IE = impact energy (Nm)

N = the number ofblows

m = mass of the drop hammer (kg) g = gravitational acceleration = 9.81 m/sec^{2}h = height of drop hammer(m)

VI. ANALYSIS OFRESULTS

Aspreviouslymentioned,oneofthemaingoalsofthisstudyistoachieveanoptimalpowderrubberratiofortheartialreplacementofthefineaggregatesintheconcretemixdesignwithanultimateobjectivetoincreasetheameliorativeeffectsontheimpactresistanceandmakeitsuitableforspecificengineeringapplications.Thelimitofthecompressivestrengthoftheconcretedependsonboth,thestrengthofthematrixandtheparticletensilestrengthoftheaggregates.Thestrengthoftheconcreteisusuallyrelatedtothemixcontentandthewatertocementratio.The28dayscompressivestrengthsoftheconcretemixesareshowninTable2.Thecomparisonbetweenthecalcul

atedcompressivestrengthandtheexperimentalresultsasafunctionofsandreplacementwithpowderedrubber isgraphicallysummarizedinFigs.1013.The28dayssplittingtensilestrengthofthepowderrubberconcretecylinderswithvaryingpercentagereplacementofpowderrubberoffineaggregatesinnormalconcretearetabulatedinTable3.Theconcretecylinderswithoutrubberfailedby splitting into two halves during the splitting tensile tests as shown in Fig. 14, whereas the rubberized concrete cylinders displayedamorecohesivebehaviorthatisfailingwithoutsplittingasshowninFig. 15.
Thereplacementofsandbypowderedrubberhasincreasedtheoccurrenceofconcretetocrackstartingunderthe impactdropload.Thefailureoccursrapidlyinrubberizedconcrete.Therefore,itcouldbededucedthattherubberwithsmallsize(noparticlebridging)hasalittleeffectindelayingthecrackspiritinconcrete.Allthespecimens aresplitintoseparatepartsundertheeffectoftheimpactforce.Novisiblecrackswerenoticedineachoftheseparatedpartsandnodislocateddolomiteparticleswerefoundacrossthefracturedsurface.Thismaybeduetothegoodbondbetweenthemortarandthedolomite.Therefore,thefavorablecrackpathisacrossthedolomiteparticlesnotaroundthesurfaceoftheparticles.Thereisnoparticle bridging found in the case of rubberized concrete because the small size of the powder rubber. The results of the ImpactstrengthandnumberofblowsareshowninTable4.

VII. CONCLUSIONS

Afterextensivelyexploringthistopicandstudyingdifferentaspectsofrubberconcretepropertiesandbehavior ,aseriesof conclusions werederived:

1 Partialfineaggregatesreplacementinconcretemixbypowderedrubberleadstoareductioninthedensityof thefinal product,becausethespecificgravityofrubberusedwaslessthanthatoffineaggregates.
2 Decreasingintherubberizedconcretestrength(compressiveandtensilestrength)withtheincreasingpowderedrubber content in the mixture is always detected as shown in Figs. 16 and 17. The strength reduction may be attributed to two reasons. First, because the rubber particles are much softer (elastically deformable) than the surrounding mineral materials,andonloading,cracksareinitiatedquicklyaroundtherubberparticlesinthemix,whichacceleratesthefailure oftherubber–cementmatrix.Second,softrubberparticlesmaybehaveasvoidsintheconcretematrix,duetothelackof adhesionbetweentherubberparticlesandthecementpaste.
3 Foradesignmixstrengthrangingbetween30MPaand50MPa,thereductioninthecompressivestrengthisconsistent andalmostataconstantratiowiththeincreaseinthepercentofpowderedrubber.Thereductioninstrengthis anaverage of 30, 35, 50, and 63% against a powdered rubber replacement of fine aggregates at 5, 10,15, and 20%, respectively.
4 Theadditionofpowderedrubberyieldsaslightimprovementintheconcretetensilestrengthatallrubberpercentagesbut stillresultsinlessimprovementcomparedtothecompressivestrengthreductionrate.
5 Theadditionofpowderedrubbertotheconcretemixresultsinanegativeeffectonthemodulusofelasticity. Thedecrease of elasticity reflects the capability of rubberized concrete to behave in an elastic manner when loaded in tension, thus improving the failure manners of typicalconcrete.
6 Rubberizedconcreteexhibitsenhancedenergyabsorptionsincetheconcretedidnotundergoatypicalbrittlefailureyetit encounteredaductile,plasticfailuremode.Actually,accordingtoFig.18,concreteofcompressivestrengthof50MPa, definitely displays a much better resiliency for rubberized concrete than plain concrete. This is not true for concrete of compressive strengths below 50 MPa, which displays a consistent reductionin resiliency.

Rubberized concrete can be used efficiently. Even though the rubberized concrete mixture has generallyareducedcompressivestrengththatmaylimititsuseincertainstructuralapplications,itpossessesanumberofdesirableproperties,suchaslowerdensity,highertoughness,andhigherimpactresistance,compared toconventionalconcrete.

Compliance with ethical standards
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