The Institution of Structural Engineers

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Mechanical Characterisation Of waste-tyre Rubberised concrete

The PROBLEM

- Year on year massive amounts of waste tyres are produced
- Build up and disposal of waste tyres is a major problem
- Few solutions - landfill, incineration and recycling
- Inadequate disposal poses a threat to human health and increased environmental risks
- Research undertaken investigating ways of developing concrete in construction with use of recycled materials
- Concrete has begun using chemicals and materials to vary its mechanical properties
- Recently the construction industry has begun investigating the inclusion of recycled rubber in concrete with extensive research focusing on the mechanical properties of the mixture.

This research aims to:

- Investigate the effects curing periods have on the overall properties
- First experimental testing of the rubberised concrete in structural applications.

MECHANICAL TESTING

- Mix Design

Previous research shows there are advantages of including waste tyre-rubber in concrete, although all research shows significant losses in compressive strength.
In this research mix design parameters have been chosen to limit the reduction of compressive strength of concrete. All mixes used Ordinary Portland Cement and the same water-cement ratio to control the overall strength of the mixes. The control mix (C) was deigned using the BRE Mix Design based on a 40N/mm^2 target design strength.
Partial rubber crumb (0.5 - 2mm) replacement of 20% and 40% of the fine aggregate was used based on previous research.
Fine aggregate replacement and rubber crumb where both chosen to limit the effects on the compressive strength of the mixes. All rubber crumb was pretreated by washing and soaking the rubber in water for 7 days prior to casting, based on previous research identifying small improvements in compressive strength.

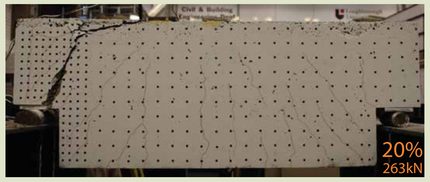
Final Mix Quantities including Rubber Crumb

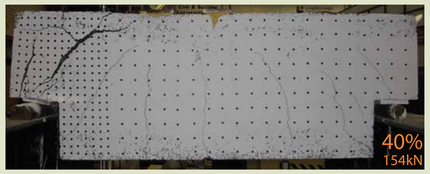
Mix Name	Rubber Content (%)	Cement (Kg)	Water (Kg)	Fine Aggregate (Kg)	Course Aggregate (Kg)	Rubber Crumb (Kg)
A	40	4.75	1.80	4.65	9.50	1.97
B	20	4.75	1.80	6.20	9.50	0.99
C	0	4.75	1.80	7.75	9.50	0.00

Per 1000mm^3 (10 cubes)

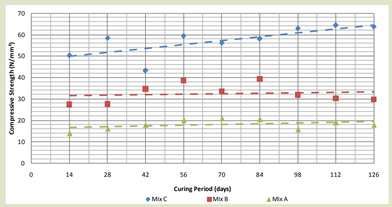
- Observations

Reinforced beams of Mix A, B and C where tested to failure. The addition of rubber crumb to the concrete reduced the spalling and eliminated the explosive brittle failure observed during testing of the control beams.
The rubber samples exhibited a controlled shear failure, with all concrete remaining intact and not exposing the reinforcing steel. The addition of rubber absorbs the energy allowing the specimens to deform and crack earlier. As the loading increased, cracking propagated slower in the rubber mixes, resulting in less extensive cracking up the beams.



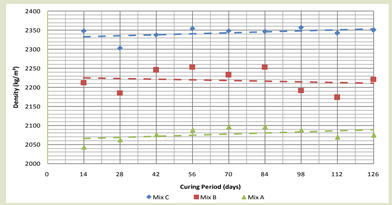


- Compressive Strength



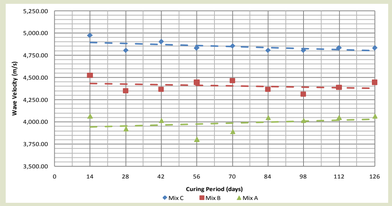
- The compressive strength of concrete decreases as more rubber is added to the mix.
- The time spent curing increases the compressive strength of rubberised concrete up to 84 days
- After which the compressive strength begins to level and drop

- Density



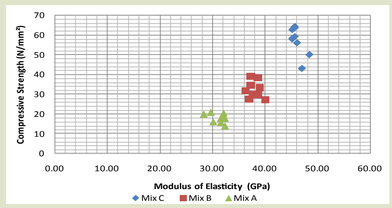
- The density of rubberised concrete decreases as the quantity of rubber increases
- There is a much stronger correlation found between density and compressive strength for rubberised concrete than regular concrete

- Sound Absorption



- Rubberised concrete is suited to damp vibrations and absorb sound
- Rubber particle slow the velocity of waves propagating through the concrete
- Increasing the wave velocity has little effect on the sound velocity

- Modulus of Elasticity



- The modulus of elasticity decreases with the increase of rubber crumb into the mix
- Rubber is more flexible than the sand it is replacing
- Rubberised concrete exhibits a more elastic behaviour than the control concrete (mix C)

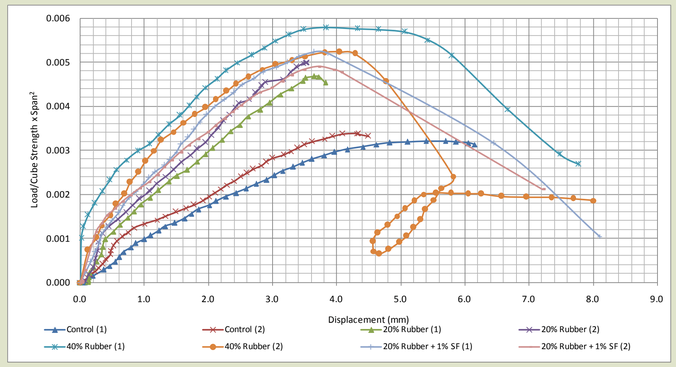
- Mechanical Properties

- Load vs Deflection

Normalisation was applied to all load values to allow for a better comparison between samples with varying concrete strengths from the different amounts of rubber crumb used in the mixes. This was carried based on principles from Buckingham Pi Theorem.

By looking at the normalisation by span:

- It is clear to see that there is no tight correlation between all the samples
- Strength of the concrete has a significant effect on the behaviour of the samples in comparison to the controlled geometry and reinforcement
- The 40% rubberised concrete mix is the most efficient at utilising its strength to prevent failure
- The standard concrete specimens experience the most displacement under loading compared to the rubber specimens which is surprising when we consider its overall stiffness
- Successful application of rubberised concrete in causing a more ductile failure and cracking control under loading
- Rubberised concrete samples displayed less deformation leading up to failure compared with the standard concrete mix



Rubberised concrete allows greater deformation to occur due to the decrease in Young's Modulus, allowing the material to deform into a new alignment. This allows the rubberised concrete to withstand post failure loading as shown by the 20% rubber crumb with 1% steel fibre mix.

STRUCTURAL TESTING

- Stuctural Application

Cube	Initial Test: Compressive Strength (N/mm²)	Initial Test: Reloaded (Yes/No)	Residual Test: Compressive Strength (N/mm²)	Residual Test: Percentage losses (%)
A10	20.97	Yes	6.44	69.29%
A12	20.57	Yes	6.39	68.94%
A14	15.83	Yes	7.12	55.02%
A16	19.04	Yes	6.48	65.97%
A18	17.87	Yes	5.44	69.56%

The addition of rubber aggregate to concrete offers increased toughness, elastic failure and reduced weight. The nature of rubberised concrete allows for a post failure load to be observed in both cube and structural testing. This is significant in providing a much safer construction material that could be used in applications where cyclic loading is applied. This residual strength is non-existent in traditional concrete and could be useful in areas such as roads, highway barriers and railway stations.

SUMMARY

The addition of rubber to concrete:

- Decreases both tensile and compressive properties
- Increases damping and absorption properties
- Reduces the density of the mixture
- Improves the safety of structural failure mode
- Offers possibility of post failure loading

Rubberised concrete has the potential to be used in a number of areas:

- Sound barriers along railways
- Road barriers
- Interior construction and false façades
- Foundations in seismic areas
- Construction prone to cyclic loading

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