Impact Resistance: Fibre Reinforcement

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The increase of terrorist attacks in recent years has led to more consideration for impact resistance against blast wave and penetration of fragments for buildings and other infrastructures.

Reinforced concrete structures subjected to impact loadings exhibit different properties from those under static load conditions. The magnitude of the localised damage is dependent on multiple factors which include impact velocity, mass, geometry, material properties of the fragments and concrete properties.

There is current research into ultra-high performance fibre reinforced concrete, which could be used to create light-weight panels that are resistant to both high speed impact and explosions. The addition of reinforcement fibres improves the tensile strength, toughness and ductility of the concrete.
I conducted an experiment to display how the addition of fibre reinforcement increases the impact resistance of a material. For experimental purposes I chose to use frozen water as my sample, which was first tested on its own and later with different fibre reinforcement. To simulate a high speed impact or a fragment from an explosion, samples were shot with an air rifle pellet at a distance of 2m. Photographic evidence was taken at each stage, so the results could be clearly compared.

Test one: Frozen water

Step 1- Put water in container and freeze:

Step 2: Place sample in rifle range:

Step 3- Shoot sample:

Step 4- Observe destruction of impact:

Test Two: Frozen water and steel fibre reinforcement (staples)

Step 1- Put water and staples in container and freeze:

Step 2- Place sample in rifle range:

Step 3- Shoot sample:

Step 4- Observe destruction of impact:

Test Three: Frozen water and steel fibre reinforcement (3 coils)

Step 1- Put water and steel coils in container and freeze:

Step 2- Place sample in rifle range:

Step 3- Shoot sample:

Step 4- Observe destruction of impact:

Test Four: Frozen water and plastic fibre reinforcement (20 straws)

Step 1- Put water and straws in container and freeze:

Step 2- Place sample in rifle range:

Step 3- Shoot sample:

Step 4- Observe destruction of impact:

Test Five: Frozen water and plastic fibre reinforcement (18 coils)

Step 1- Put water and coils in container and freeze:

Step 2- Place sample in rifle range:

Step 3- Shoot sample:

Step 4- Observe destruction of impact:

Observations

In test one the sample of frozen water was impacted with the air rifle pellet. The sample was completely destroyed, as it was split into many separate pieces which consequently fell apart. The sample had no structural integrity.

Test two, which was a sample of frozen water containing steel fibres reinforcement in the form of staples, was shot with the air rifle. In this case, the section of the sample above the point of impact was shattered into many pieces, but the part of the sample below and at the sides of the point of impact remained mostly intact.

When test three, which was a sample of frozen water containing steel fibre reinforcement in the form of steel coils was impacted it managed to mainly maintain integrity throughout the sample. There was only some minor cracking around the point of impact.

Test four was a sample of frozen water containing plastic fibre reinforcement in the form of plastic straws. After being impacted the frozen water split laterally along the straw at the point of impact. The section above the point of impact split rather cleanly away from the bottom half. The bottom half managed to remain intact.

Once test five, which was a sample of frozen water containing plastic fibre reinforcement in the form of plastic coils, was impacted, the section above the point of impact was split into cylindrical segments which broke away, while the part below the point of impact contained slight cracking.

Conclusions

The tests have been successful in showing how the addition of fibre reinforcement can increase the impact resistance of a material. From the results shown, it displays that there is a certain amount of fibre reinforcement required to stop the sample from failing. The way in which the fibre reinforcement was placed may also have a factor to play, as in the example of the straws; if it had been cross hatched it most likely would have been more effective in holding the sample together when impacted.

Frozen water proved to be an ideal medium to observe the effects that a projectile impact has on a fibre reinforced material. The same principles would apply to other reinforced materials i.e. fibre reinforced concrete.

References

http://www.claisse.info/special%20papers/zhang_full_text.pdf

http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/D041198/1