Self-Healing Concrete

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Abstract

Self Healing material is an emerging and fascinating area of research inspired by biological systems in which damage triggers an automatic healing response. Our system utilizes stress as an environmental stimulus for self-healing concrete. Microcapsules filled with sodium silicate is incorporated randomly into concrete mixture. As a crack propagates it is attracted to the microcapsule and tip of crack ruptures the shell, releasing the healing agent. As the healing agent flows into the crack via capillary action it interacts with dispersed catalyst, to form the calcium-silicate-hydrate gel ,which prevents the propagation of the crack. It has been shown that the healed material recovers a large portion of its original properties. Microcapsule size and microcapsule loading is very important to self healing effectiveness of the material. Our analysis includes varying the microcapsule loading and microcapsule size in concrete samples to check the effect on recovery of the sample after two successive mechanical loads. Microcapsule diameter is determined by stirring rate. It is further been explored if the microcapsules can now be replaced by gelatin capsules and what effect it has on self healing properties of the material. This material has various applications in civil engineering and infrastructure materials for building mitigation.

Relevance

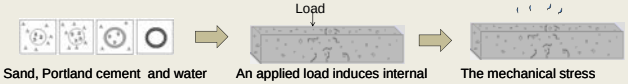
Concrete is the most used construction materials worldwide.Thus self-healing concretes has a huge significance in day to day life.

- To make infrastructure more safe and durable
- Protection of materials from weather
- Production of less concrete, resulting in lower emission of carbon dioxide .
- Self-healing materials play an important functions such as load bearing.

Accomplishments Through Current Year

- Scientific publications on Self-Healing Materials increased from < 20 in 2001 to 114 in 2009
- Self-healing of damage material can significantly increase the effective lifetime of all construction materials
- Costs is also cut down
- There is substantial saving of resources and energy
- It has applications as an anti-corrosive agent.

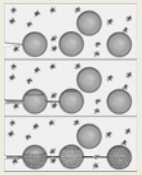
Self Healing System



Sand, Portland cement and water Microcapsules containing the Healing agent are incorporated in concrete.

An applied load induces internal microcracking in concrete.

The mechanical stress ruptures capsule to release healing agent that repair crack



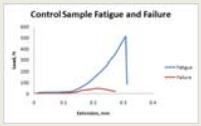
Self-healing concept,where the crack breaks capsule releasing healing agent , which reacts with catalyst , forming calcium-silicate-hydrate gel, and heals crack.

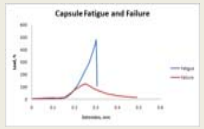
Preparation of polyurethane microcapsule

- Sodium silicate encapsulated in polyurethane shell .
- Water is dispersed in an organic phase of toluene and the droplets are stabilized by two surfactants.
- The diisocyanate and water droplets react at the interface of the oil and water, producing a thin shell.
- Reaction time is 4 hours , shell matures into solid polyurethane capsule .

Testing of Self-Healing System

- Microcapsules with healing agent are incorporated into concrete.
- Samples with varying size and different loading of microcapsules prepared .
- . Each sample was fatigued in a three point bend test
- The load forms crack and ruptures capsules
- .After short period of time, the samples are finally tested to failure and strengths compared.





Three Point Bend results show that control samples recover about 10% of its strength compared to 26% recovered by samples containing healing agent.

Control	Initial Max Load, N	Max load after damage, N	Recovered Strength, %
1	512.889	46.734	9.11
2	490.684	57.555	11.7
3	541.948	76.604	14.1
4	470.582	66.414	14.1
5	525.821	69.613	13.2

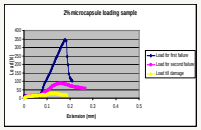
Table 1

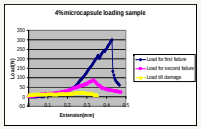
Capsule	Initial Max Load, N	Max load after damage, N	Recovered Strength, %
1	495.6651	124.373	25.1
2	416.6876	85.927	20.6
3	476.583	125.231	26.3
4	513.821	127.525	24.8
5	528.222	130.555	13.2

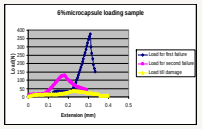
Table 2

Table 1 and 2 show the results for control vs. capsule samples. Overall, the sample contianing the microencapsulated healing agent consistently performed 10-15% better then the samples that do not contain the healing agent.

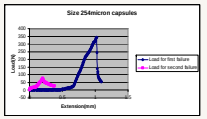
Results

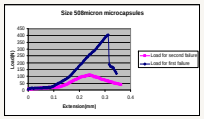






Three point bend results for samples containing 2%, 4%, and 6% by weight microencapsulated healing agent.It has been seen that as the loading increases the healing efficiency also increases. Healing is governed by the amount of healing agent released when capsules are ruptured thus sealing the crack .The number of capsules that are ruptured n=p*N , where N is the total number of capsules in sample ,p is the probability that the center of capsule lies in ruptured zone.





Three point bend results for samples containing varying size of microcapsules at a specific weight fraction. In this case when the weight fraction was less the samples with larger capsules perform better , as they are more compact and there is more probability of a large capsule to rupture releasing healing agent.

2% loading	Initial max Load (N)	Max load at Failure (N)	Recovery %	Max load at damage (N)	Recovery %
1	282.6139	68.33242	24.18	19.64248	6.95
2	346.258	87.21004	25.19	21.57147	6.22
3	227.2231	60.8553	26.78	19.17728	8.43
4% loading					
1	363.1494	110.9988	30.56	22.63931	6.23
2	402.2372	108.5239	26.9	28.22365	7.02
3	300.0248	85.85623	28.61	25.58451	8.53
6% loading					
1	378.1095	129.0368	34.12	36.52441	9.65
2	493.3637	177.5164	35.9	52.0863	10.55
3	399.2038	121.6343	30.46	31.56283	7.91

254 micron capsules	Initial max laod (N)	Max load at Failure(N)	Recovery %
1	344.4498	77.01782	22.35
2	219.2162	53.79091	24.53
3	244.7751	60.76173	24.8
508 micron capsules			
1	277.1714	70.18761	25.32
2	402.438	109.0964	27.11
3	373.4821	108.4273	29.03

Conclusion

- Increase in microcapsule loading increases healing efficiency, but there may be a possibility that after a certain loading the efficiency will not be affected with increase in capsules.
- Samples containing larger capsules had a better healing efficiency at a fixed low loading
- Samples with small capsules need more % loading for better healing as more capsules are required to deliver same amount of sodium silicate to the fracture plane .

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