Characterization of cement and concrete exposed to laser radiation at 10.6 um

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ABSTRACT

In this paper, we report preliminary results of molecular structural changes in cement and concrete caused by laser radiation at 10.6 \( \mu \text{m} \). One of those structural changes is the generation of glazes. At low laser powers, the glazes are small and lined up while at high powers, the glazes are bigger and randomly distributed. In the not exposed to laser radiation concrete, the Raman spectrum presents weak peaks at 200 \( \text{cm}^{-1} \), 550 \( \text{cm}^{-1} \), 700 \( \text{cm}^{-1} \), 750 \( \text{cm}^{-1} \) and 1 150 \( \text{cm}^{-1} \). However, these peaks are amplified by laser exposure and other peaks appear at 800 \( \text{cm}^{-1} \) and 1 050 \( \text{cm}^{-1} \). The intensity of all the peaks is dependent on laser radiation power.

Keywords: CO\(_2\) laser, Cement, Concrete, Raman spectroscopy.

1. INTRODUCTION

Some materials have necessity to use tools where physical contact between tool and material is non-existent. Lasers have unique characteristic because they can be used in materials processing, so the laser is an easy tool to handle\(^1\).

One such material is concrete, which is a composite material consisting of an array of fine and coarse aggregate pieces embedded within an ordinary Portland cement\(^2\).

Various methods have been developed to accelerate the strength gain of concrete with the aim of satisfying increasing accommodation demands economically and in a short period of time. Various types of fine aggregate are being used in concrete mixtures. The type of fine aggregate used changes the geometric properties of cement paste, and effects not only the paste formation during heat treatments but also the properties of concrete\(^3\).

The effects of both elevated and freezing temperatures on concrete behavior have been extensively studied; for example, the compressive strength of concrete decreases as the temperature increases. In general, at nearly 100\( ^\circ \text{C} \) the physisorbed moisture begins to evaporate. Although the elasticity reduces by about 10 \% - 20 \%, the compressive strength remains unchanged. As the temperature exceeds 300 \( ^\circ \text{C} \), the hydration water of silicates is released. This causes the cement to contract. The aggregate, however, expands. In the range from 450 \( ^\circ \text{C} \) to 500 \( ^\circ \text{C} \) the compressive strength decreases slowly, whereas at higher than 500 \( ^\circ \text{C} \) it descends rapidly. As temperature increases to around 600 \( ^\circ \text{C} \), the quartz crystals in the aggregate undergoes an \( \alpha\text{-}\beta\text{-SiO}_4 \) conversion. The specific volume increases drastically. The calcium hydroxide begins to dehydrate, which causes the concrete structure to deteriorate. As temperature approaches 900 \( ^\circ \text{C} \), calcium carbonate also decomposes. At this time, all free or bound water goes away. The compressive strength approaches zero\(^4\).

Lasers applications like CO\(_2\) laser include works like removal of the contaminated surface layer of concrete and the modifying the surface appearance and surface properties of cement-based materials. The laser treatment produced novel surfaces, with surface textures, properties and appearance unique to treated materials\(^5\).

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Laser produces superficial changes at the concrete; further, as the traverse speed increased, the depth of the laser interaction area generally decreased.

Laser at 10.6 µm interact with the water molecule and present advantages respect other lasers, for example high power diode laser. The difference between the pull-off strength of the CO₂ and high power diode laser can be attributed to the fact that the heat affected zone after high power diode laser was much smaller than that of the CO₂ laser.

Also lasers, we need a method to identify the structural molecular changes in cement and concrete.

The Raman Spectroscopy is a tool very used in material characterization because it permit us detect whether any change of the investigated materials has occurred. However, the sensitivity of certain materials to laser irradiation can be an advantage, if the study of laser-induced oxidation and crystallizations processes becomes possible.

2. EXPERIMENTAL PROCEDURES AND RESULTS.

2.1. Sample preparation
The concrete samples were prepared using 1 310 g of sand, 900 g of ordinary Portland cement, 900 g limestone aggregate and 620 ml of distilled water. For cement samples we use 700 g of ordinary Portland cement and 390 ml of distilled water. All materials were well mixed until obtain a suitable past. These pasts were placed in PVC tubes of 1.5 in diameter and 3 in height.

2.2. Sample laser irradiation
After 48 hours, the samples of concrete and cement were exposed to CO₂ laser radiation and were analyzed with Raman Spectroscopy. In all experiments, we use a CO₂ laser with a focal length of 0.6 cm, spot size of 0.8 cm and 1.27 cm/s irradiation speed. For cement sample, we use a laser power of 15 W while the concrete samples were treated with powers of 28 W, 31 W and 32 W, respectively. With these powers we can see the formation of crystals on concrete samples.

The Raman Spectroscopy was used to identify the peaks formation and intensity after the cement and concrete samples were exposed to CO₂ laser radiation.
2.3. Results
In Fig. 1 we show the Raman spectra of concrete samples with and without exposition to laser radiation. The concrete samples not exposed to laser radiation, present weak peaks at 200 cm\(^{-1}\), 550 cm\(^{-1}\), 700 cm\(^{-1}\), 750 cm\(^{-1}\) and 1150 cm\(^{-1}\). However, these peaks are amplified in the concrete irradiated with laser and other peaks appeared at 800 cm\(^{-1}\) and 1050 cm\(^{-1}\).

Fig. 2. Raman spectra of concrete exposed to laser radiation at different powers.

Fig. 3. Scanning electron micrograph concrete exposed to laser radiation using a power of (a) 32 W; (b) 31 W; and (c) 28 W.
Scanning electron micrographs of concrete samples irradiated with laser are shown in Fig. 3. The concrete samples exposed to higher laser powers present well defined crystals and they are random distributed. Until now, we do not know the chemical identity of these crystals.

![Cement exposed to laser irradiation](image)

Fig. 4. Raman spectrum of cement exposed to laser radiation power of 15 W. We can observe a characteristic peak at 700 cm$^{-1}$, which is also observed in concrete samples exposed to any laser radiation power.

### 3. CONCLUSIONS

Laser radiation causes molecular structural changes in cement and concrete samples. These structural changes are dependent on laser radiation power. We have identified a characteristic Raman peak at 700 cm$^{-1}$ for cement and concrete samples, with or without laser exposure.

### REFERENCES

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