TiO_2 입자의 사이즈가 바인더젯 3D 프린팅 시멘트계 재료의 특성에 미치는 영향

Effect of nano-TiO_2 size on the properties of cement-based materials produced by binder jet 3D printing

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Abstract
With the development of nano-reinforcement technology, TiO_2 nanomaterials have received widespread attention as one of the additives without pozzolanic reaction, which can be used to improve the mechanical properties of cement-based materials. Meanwhile, with the development of additive manufacturing technology or known as 3D printing technology, its application in the construction field has also got noticed. Therefore, in this work, the effect of three sizes of TiO_2 on the compressive strength of hardened cement-based materials fabricated by binder jetting 3d printing was evaluated. According to the results, the TiO_2 particles with larger sizes can provide better reinforcement to the hardened cement due to its more significant filling effect.

키 워 드 : 바인더젯 3D 프린팅, 나노 TiO_2, 시멘트계 재료, 나노보강재.
Keywords : binder jet 3D printing, nano-TiO_2 ,cement-based materials, nano-reinforcement

1. 서 론

Binder jet 3D printing is one of the additive manufacturing methods suited for cement-based materials, which is a technique of liquid binders selectively sprayed layer by layer onto a dry powder bed based on a customized model and eventually stacked into a product. Furthermore, the technical characteristics of binder jet 3D printing require that the cement-based materials used should have relatively short setting time, fast hydration reactions, and the ability to obtain strength rapidly in the initial stages. Hence, some cement-based materials with these properties were used to investigate their potential for binder jet 3D printing, such as calcium sulfoaluminate (CSA) cement and calcium aluminate cement (CAC). Moreover, with the development of nanotechnology, the usage of TiO_2 nanoparticles as a reinforcing agents to improve the properties of cement-based materials has been widely investigated [1,2]. In this paper, the 1% of three different sizes of TiO_2 particles were mixed into the commercial cement-based materials, and specimens were prepared using binder jet 3d printing method. After printing, the sample was placed into water for curing until reaching the test period of compressive strength, and the X-ray diffraction was utilized to analyze the hydration products.

2. 재료 및 방법

The commercial cement-based powder (CP, ordinary Portland cement, amorphous calcium aluminate, sand, and additives) obtained from the CONCR3DE company, was used as dry materials. The ink used in the printing process was G3CO_binder (polyol polymer, water, and additives), which was a water-based binder for binder jet 3D printing, also provided by the CONCR3DE Company. Figure 1 illustrated the preparation process of specimens. The 3D models of specimens were created via SolidWorks, and the powder used in the 3D printing was obtained through dry mixing of cement-based powder and 1% TiO_2 particles with different sizes. Three sizes of anatase TiO_2 powder were purchased from Sigma-Aldrich, i.e., small-sized

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TiO_2 (ST, 8nm), medium-sized TiO_2 (MT, 110nm), and large-sized TiO_2 (LT, 150nm).

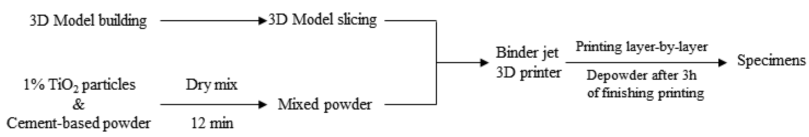

Figure 1. The workflow of specimen production via binder jet 3d printing process.

3. 결 론

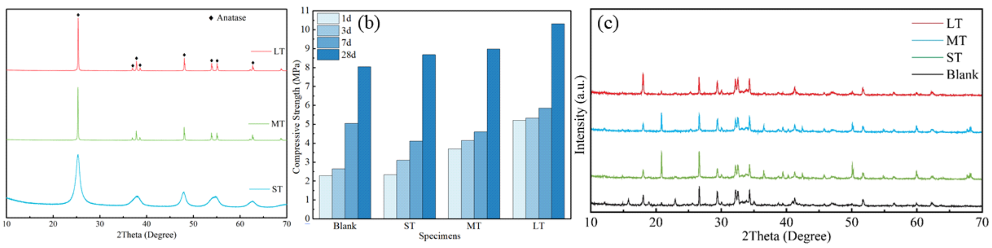

Figure 2. XRD pattern of Anatase TiO_2 particles (a), compressive strength of specimen cured in water (b), and XRD pattern of specimens at 28d (c).

The crystalline structures of the various sized TiO_2 were verified via XRD as shown in Figure. 2(a), the peaks of TiO_2 were situated at 25.3°, 36.9°, 37.8°, 38.6°, 48.0°, 53.8°, 55.0°, 62.1°, and 62.6°, which related to the (101), (103), (004), (112), (200), (105), (211), (204), (213), and (204) planes of anatase phase, respectively. In addition, the diffraction peaks were broadened due to the reduction of particle size. Figure 2(b) showed the compressive strength of the specimens cured in water after 1, 3, 7, and 28 days. It was observed that the strength of the samples gradually increased with the curing time and the size of the particles. Meanwhile, the most significant improvement in compressive strength was observed at 28 days. This was attributed to the nucleation effect and the filling effect offered by TiO_2, i.e., it provided more nucleation sites for the formation of hydration products (Figure. 2(c)) and filled the voids inside the specimens. In the early stage of hydration (before 7d), the lack of significant increase in compressive strength may be due to curing in the water, which diluted the binder inside the specimen and leaved insufficient bonding between the layers. Based on these results, we suggested that the TiO_2 particles were feasible for binder jet printing technology and that the properties of cement-based materials were enhanced due to their nucleation and filling effects.

감사의 글

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