DRYING SHRINKAGE, AUTOGENEOUS SHRINKAGE, THERMAL STRAIN AND ELASTIC STRAIN OF STEEL-MAKING SLAG CONCRETE

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Carbon dioxide (CO_2) is the principal greenhouse gas believed to be contributing to global warming. The vast majority of man-made CO_2 emissions come from the process of iron and cement works. The load of the construction works with iron and cement to environment is extremely big. Many ironworks are operating in the Seto Inland Sea area, Japan. Not only blast furnace slag sand but also many types of steel-making slag are producing. Just blast furnace slag can supply with all sand for ready mixed concrete in this area. On the other hand, good quality natural sand, i.e. sea sand and river sand are difficult to use in this area. Aggregates including sand are among the most basic materials fulfilling human needs. They are used for infrastructures fundamental to human well being, such as building roads, dams, bridges, dikes, etc. It is one of the first domestic resources to be utilized in developing economies. Industrialized economies continue to consume large quantities. As an alternative sand to sea sand and river sand, steel-making slag sand, which can supply huge quantities, have a number of desirable attributes.

Steel-making slag concrete consists of just by-products at ironworks. The main binder is grand granulated blast furnace slag. Cement is basically not necessary. The sand and the gravel are blast furnace slag or steel-making slag. Steel-making slag concrete doesn't use any natural aggregate, either. The calcium hydroxide leaching from steel-making slag acts as an alkali activator of ground granulated blast furnace slag. Steel-making slag concrete can be hardened by itself without any cement. Blast furnace slag sand was recognized as meeting JIS A 5012 standards in 1981, and has also been stipulated in guidelines for the Japan Society of Civil Engineers. It is also stipulated as JIS A 5308 (ready-mixed concrete). However, steel-making slag has not been recognized to use as

ordinary concrete aggregate, yet.

Steel-making slag concrete contains many iron, silicon and phosphorus. They are essential elements for living things. And, the leaching of heavy metal from steel-making slag concrete is very little. In comparison with normal cement concrete, a lot of marine life is easy to grown up on steel-making slag concrete. It is known that steel-making slag concrete can improve the circumstance in marine for marine life.

In this study, it is shown that concrete with just by-products from the ironworks can be produced with the same performance of conventional concrete in calm condition. Steel-making slag concrete is expected as a material reducing environmental load. Steel-making slag concrete is, however, used for foot protection block and small marine block, now. The purpose of this study is to enlarge the cover field of steel-making slag concrete.

The strength of steel-making slag concrete is 20-70 N/mm^2 at 28 days. Resistance to carbonation of steel-making slag concrete and resistance to corrosion of steel rod in steel-making slag concrete are high for a long time due to calcium hydroxide leaching from steel-making slag. However, resistance to freezing and thawing of steel-making slag concrete is quite low. The mechanism of low resistance to freezing and thawing is clarified in this study. The method to improve the durability of steel-making slag concrete is also shown. An entrained air by AE agent is formed by calcium ion. The paste just with ground granulated blast furnace slag cannot contain entrained air by AE agent because enough calcium ions cannot be produced by the hydration with water and ground granulated blast furnace slag. Big size air is formed around steel-making slag because of calcium hydroxide leaching from the steel-making slag. That's why resistance to freezing and thawing is low. In order to improve the resistance to freezing and thawing of steel-making slag concrete, it's necessary to use cement, fly ash and blast furnace slag sand. Cement is used to entrain the air by AE agent. Fly ash is used to consume the extra calcium hydroxide in steel-making slag concrete. Blast furnace slag sand is used to restrain the calcium hydroxide leaching from sand. Then, the resistance to freezing and thawing of steel-making slag concrete is as high as that of AE cement concrete.

Elastic strain, thermal strain, autogeneous shrinkage strain and drying shrinkage strain of steel-making slag concrete are also examined to design large precast concrete with steel-making slag concrete. Autogeneous shrinkage of steel-making slag concrete is very small due to high water absorption of steel-making slag, even when water to binder ratio of the concrete is quite small. Drying shrinkage strain at ultimate drying time of steel-making slag concrete is much bigger than that of cement concrete. Furthermore, drying shrinkage strain of steel-making slag concrete develops very slowly with a lapse of time. They are due to the effect of high water absorption of steel-making slag. However, it is clarified that drying shrinkage strain of steel-making slag concrete can be predicted by JSCE model when water content in aggregate is taken into consideration. That is, when total water content, i.e. both unit water content in concrete and water content including in aggregate are used for the term of unit water content in the prediction equation, the predicted drying shrinkage strain fits with experimental data, well. Furthermore, it is also shown that steam curing can reduce the drying shrinkage strain of concrete with grand granulated blast furnace slag, such as steel-making slag concrete. On the other hand, Young's modulus, thermal expansion coefficient of steel-making slag concrete is as same as those of conventional cement concrete. The effect of type of aggregate on those coefficients is small. As shown in this study, the deformation of steel-making slag concrete can be predicted in design. It is possible to utilize the steel-making slag concrete in manufacturing of plain concrete structure such as large precast concrete armour unit or concrete block for retaining wall and revetment.

Steel-making slag concrete is typical environmental conscious material. It can release environmental load by construction when it applies to concrete products adequately. This study shows the possibility of concrete with ordinary performance by using low quality materials, too. The results shown in this study provide not only good utilization of industrial by-product but also the improvement of conventional concrete performance.