AN INTRODUCTION OF SLAG AND PORTLAND SLAG CEMENT

INTRODUCTION : Slag is a by-product of steel industry. More precisely, when a mixture of iron ore, limestone and dolomite in controlled ratio is fed to iron blast furnace and heated up to 1450 -1500 ^{0}C temperature, is converted into a molten stage. The iron being heavier in weight is accumulated at bottom and rest of the part of molten mainly the impurities (SiO_2, Al_2O_3, CaO, MgO and Mn_2O_3) are floated on top surface of melt iron. This lighter weight molten is called slag and is diverted to separate it from Iron. Since slag is a mixture of mainly SiO_2, Al_2O_3, CaO, MgO and heated upto molten stage, is having hidden hydraulic properties. These hidden hydraulic properties can be exhibited by slag if it is mixed in finely ground form with water and a powdered source of $Ca(OH)_2$ i.e. Portland clinker.

Thus if slag is inter ground with clinker and adequate amount of gypsum or finely ground slag is blended with finely ground clinker along with an adequate quantity of gypsum will exhibit cementitious properties.

It is pertinent to mention here that slag is having approximately 15-17% MgO content (Coming from Dolomite) which is over burned/hard burned at 1500 ^{0}C tend to hydrate very slowly, resulted in unsound behavior of cement in terms of volume stability. Cement shows this phenomenon because of MgO , if it is present in periclays form. But if we can cool slag very fast or even quench in the stream of water, it convert periclays into glassy form and entire slag is granulated. This process of rapid quenching of slag is minimizing crystallization and forms “granulated slag”, which is composed mainly of calcium alumino silicate glass. Formation of this glass in slag provides cementitious properties when it is mixed with water after inter grinding with clinker and gypsum or finely ground slag is blended with ground clinker along with gypsum. Thus the cement produced with slag, clinker and gypsum is called Portland Slag Cement (PSC). Portland Slag Cement known since 1700s, when the material was combined with lime to make mortars. The first Portland Slag Cement was produced in US in 1896. Granulated slag was used in the manufacturing of blended Portland cements in US till 1950s.However, from 1950s onwards Portland Slag Cement become available in other countries as a separate product.

QUALITY OF SLAG : From the above it is crystal clear that slag can be used in cement manufacturing by replacing OPC clinker. To produce good quality of Portland Slag Cement on consistent basis in India, Bureau of Indian Standards has formulated certain guidelines to define the quality of slag used in Portland slag Cement under the IS:12089-1987 (Reaffirmed in 1999), Specifications For Granulated Slag for Manufacture Portland Slag Cement. Specifications are as follows.

a) Chemical Requirement : (Tested as per IS:4032 -1985)

Manganese Oxide - 5.5 % Max Magnesium Oxide - 17.0 % Max Sulphide Sulphur - 2.0 % Max

Slag should satisfy one of the following condition based on the oxides tested as per IS:4032-1985 (reaffirmed in 1990)

i) $(CaO+MgO+2/3\,Al_2O_3)/(SiO_2+2/3Al_2O_3) > 1.0$ or ii) $(CaO+MgO+Al_2O_3)/SiO_2 > 1.0$

However in case of slag containing Manganese Oxide (MnO) more than 2.5 % , then it should satisfy following relation.

iii) $(CaO+MgO+Al_2O_3)/(SiO_2+MnO) > 1.5$

b) Slag should not contain Insoluble Residue more than 5 % , if it is tested as per IS : 4032-1985 (Reaffirmed in 1990)

c) Slag should have glass content not less than 85 %, when it is tested with Optical Microscope.

USAGES OF PORTLAND SLAG CEMENT : Portland Slag Cement is most widely used in concrete application as under :

- Concrete pavements
- Mass concrete applications, such as dams
- Pre-stressed or post-tensioned concrete
- Structures and foundations
- Precast concrete, such as pipe and block
- Concrete exposed to water and marine applications
- High-performance/high-strength concrete, used typically in high-rise buildings or bridges to give 100 year service life.

QUALITY OF PORTLAND SLAG CEMENT : In our country, Bureau of Indian Standards has formulated the Quality Specifications to Manufacture and use Portland Slag Cement as given below. Portland Slag Cement Specifications IS : 455-1989 (reaffirmed 1995).

The key quality parameters of Portland Slag Cement should be maintained as under.

a) Chemical Requirement :

- Magnesium Oxide (MgO)	10.0 % Max	- Sulphur Trioxide (SO_3%)	3.0 % Max
- Sulphide Sulphur (S)	1.5 % Max	- Loss on ignition	5.0 %Max
- Insoluble Residue	4.0 % Max	- Chloride	0.05 % Max

b) Physical Requirement : Fineness > 225 M^2/Kg

Setting Time :

- Initial Setting Time > 30 Minutes Final Setting Time < 600 Minutes

Soundness :

- Le-Chatelier Expansion < 10 mm Autoclave Expansion < 0.80 %

Compressive Strength :

At 72 +- 1 h > 16 MPa At 168+- 2 h > 22 MPa At 672 +- 4 h > 33 MPa

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ADVANTAGES OF USING PORTLAND SLAG CEMENT : Following are the advantages of using Portland Slag Cement.

Portland Slag Cement improves the Properties of Fresh Concrete :-

Slag cement improves the workability, placement and consolidation of concrete. Slag cement is compatible with chemical admixtures in a similar manner as to OPC concrete. Slight adjustments in admixture dosages may be necessary to achieve desired results.

Portland Slag Cement improves Concrete Strength and Elastic Modulus :-

Portland Slag Cement provides higher level of compressive strength in concrete when compared with ordinary portland cement (OPC) concrete of equal cement content. Normally 40-50% slag addition is desirable to achieve optimum compressive strength. Concretes made with Portland Slag Cement will generally exhibit higher flexural strength for a given level of compressive strength. Modulus of elasticity follows the same relationship as in OPC concrete, when based on compressive strength. Thus, with the higher compressive strengths achievable with Portland Slag Cement, structural stiffness can be enhanced, and load deflections minimized.

Portland Slag Cement reduce Permeability and Corrosion :-

Low permeability is essential for long-term durability, especially with regard to corrosion resistance of reinforcing steel. The additional Calcium Silicate Hydrate formed and denser cement paste in slag cement concrete reduce pore size and reduced concrete permeability. Low permeability reduces the ingression of harmful substances (such as chlorides and sulfates) and the availability of water to catalyze harmful chemical reactions within concrete.

Portland Slag Cement Improves Resistance to Alkali-Aggregate Reaction :-

Alkali Aggregate Reaction occurs when the alkali in portland cement react with reactive Silica of aggregates to form an expandable gel that causes the concrete to crack, swell and prematurely deteriorate. Portland Slag Cement mitigates Alkali Aggregate Reactivity by reacting with the alkalis in portland cement and making them unavailable for reaction.

Portland Slag Cement Mitigate Sulfate Attack :-

Sulfate attack occurs when sulfates, found in seawater and some soils, react with Tri Calcium Aluminate in portland cement. This causes an expansive reaction and resulting deterioration of the concrete structure. Since Portland Slag Cement is containing very less Tri Calcium Aluminate, and thus lowers the total amount of Tri Calcium Aluminate available for reaction.

Portland Slag Cement Reduce Heat and Cracking in Mass Concrete :-

Mass concrete require low temperature differential between the surface and center of concrete to avoid thermal cracking. In cement Tri Calcium Aluminate is one of the main source of heat of hydration. Since Tri Calcium Aluminate is very less in Portland Slag Cement resulting in lowering the heat of hydration and finally low temperature differential, which makes Portland Slag Cement most suitable for mass concrete.

Low life cycle cost of concrete :-

Longer durability of concrete made with Portland Slag Cement resulted into low life cycle cost.

Manufacturing & Usages of Portland Slag Cement reduce Global warming :-

Global warming is one of the Global issue and needs to be addressed by each and every one of us on the earth. Usages of slag in Portland Slag Cement manufacturing is reducing the clinker consumption resulting in lowering the generation of Green House Gases (GHG) CO2 in atmosphere. The manufacture of slag cement not only lessens the burden on landfills, but also reduces air emissions at steel plants through the granulation process (as compared to the traditional air-cooling process).

Manufacturing of Portland Slag Cement requires nearly 50 percent less energy as compared to produce a ton of Ordinary Portland Cement. This again reduce the generation of Green House Gases (CO_2).

Thus in nut shell , we can say that using Portland Slag Cement is not only giving good quality of concrete but also helping in addressing the Global Warming issue as well as conserving natural resources, minimizing the pollution load on Environment.