3. SYSTEM DEVELOPMENT

3.1 Introduction

Human activities inevitably produce waste that could be simply defined as items unwanted by their owner that cannot be readily sold or given away to someone else. Throughout history, the basic approach to waste has been to dispose of it and they have been dumped, buried or burned, in combination with moving either the people or the disposal site in proximity of living and disposes become too unpleasant. Photograph 3.1: (a, b, c.) In the study area the limitations to this approach to waste have become unavoidably obvious.

The growth of the steel industry, which causes the extra waste of slag, which is very difficult to dispose of it is non-hazardous material. But due to non-hazardousness, we should not take care for the disposing of it safely. Though it is a waste product, it can be utilized for replacing the natural aggregate. For different construction activities, we used soil such as foundation of building, bridge, and dam. In the replace of this soil, we can use the wastage of steel industries slag. Steel furnace slag is the non-metallic product consisting essentially of calcium silicates with fused oxides of iron and aluminum that is developed in a molten condition simultaneously with steel in a basic oxygen furnace.

The material is produced in a molten condition simultaneously with steel in a basic oxygen furnace and is a predominantly crystalline, solid rock-like material. Slag is a broad term covering all non-metallic co-products resulting from the separation of a metal from its ore. Its chemistry and morphology depend on the metal being produced and the solidification process used. Slag can be broadly categorized as ferrous (iron/steel) and non-ferrous (copper, lead/zinc) depending on the industry from which they come. Non-ferrous slag makes up only 12 percent of the total annual production but, India dreaming about second place in the world for manufacturing the steel i.e. about 90 Million tons per year. It means that 18 million tones of slag generated per year. This slag can reduce the reduction of natural aggregates per year.
That will always helpful for protecting the natural resource for protecting the environment friendly. From the tests conducted on slag it is clear that we can replace the steel slag anywhere like for the construction of the road, we can replace natural aggregate by slag aggregates.

Photograph 3.1: (a, b, c): Dumping of Steel Slag at MIDC Area, Jalna
Steel Slag is found in the form of big pebbles. It is crystalline in microstructure and non hydraulic in nature. The microstructure and distribution of Steel Slag were studied. Microphotographs of the sample are shown in Figure 3.1, 3.2, 3.3 and 3.4. From the Figure it can be observed that quartz iron oxide aluminum oxide and various silicates are predominantly present. It is clearly observed that most of the particles are spherical structure with few irregular particles. The surfaces of spherical particles are found to be irregular and round as it is a high calcium steel slag with particle size varying from 0.075μm to 80μm.

Figure 3.1: Microstructure of Steel Slag 1

Figure 3.2: Microstructure of Steel Slag 2
Figure 3.3: Microstructure of Steel Slag 3

(Courtesy of Figure 3.1, 3.2, 3.3, 3.4 from National Institute of Technology, Rourkela)

Figure 3.4: X-Ray Diffraction of Steel Slag

(Courtesy of Figure 3.1, 3.2, 3.3, 3.4 from National Institute of Technology, Rourkela)
3.2 Scope for the investigation

In this research, a comprehensive experimental program was undertaken to evaluate the feasibility of utilizing steel slag [BOF and EAF slag] as geo-materials. The preliminary aim of investigation is to conduct the experimental work and study the properties of slag available at MIDC Jalna and the properties of soil.

In India being the developing country we cannot develop the separate expensive infrastructure for the treatment of waste generated.

This investigation helps us to use crushed steel slag for the replacement of the natural aggregate, and mixing steel slag to the soil for improving soil properties to some extent, thereby using waste and saving and protecting the environment. Thus helps in the economic development of the country as well as survival for the fittest. The improvement of soil is carried out to improve the properties of the soil. The slag is easily available; no skill labour is required for the same. It will be helpful for the nature from the degradation of the aggregate.

At present the number of steel industries are upcoming, hence it is high time to think about the waste steel slag generated in these steel industries, we should take care for utilizing the slag by replacing the natural resources available. From the literature history it is clear that we can use this slag in the construction industry.

So it is necessary to study the characteristic of the slag generated at MIDC Jalna, the steel zone of Maharashtra. For this purpose steel slag is collected from MIDC Jalna and locally available rock from the Jalna is used for the finding out the different characteristics.

3.2.1 Scope of the experimental work

1) To study the different geotechnical properties of steel slag related to its use in road construction and its cost analysis.

2) Soil modification by the application of steel slag.
3.3 Materials

Sample Soil and Rock: - Locally available Soil and Rock has been taken for the investigation.

Steel slag: - Steel slag is available as a waste material at Jalna MIDC area

3.3.1 Steel Slag

Steel slag is also locally available at Jalana. At MIDC this slag is available at free of cost. Ingot/ Billet Industrialists are also giving this slag at free of cost because it is none of their use. The steel slag is collected from SRJ Pitty’s Group of Industries, Metaroll Industries, Dhanlaxmi Steel Industries and Gajlaxmi Steel Industries. The typical chemical composition, physical properties of slag and the rock soil are as follows.

3.3.1.1 Chemical properties

Blast Furnace slag is produced from the melting of iron ore and limestone or dolomite. Therefore, blast furnace slag is a lime based material and has a basic PH. The principal constituents of steelmaking slag are calcium silicates and alumino-ferrites with fused oxides of calcium, iron, magnesium and manganese. Like blast furnace slag, steel slag oxides are combined when cooled to form various forms of minerals common to both lime and silica based materials. Free lime or free oxides of calcium and/or magnesium is available which is dissolved with water as it percolates through the slag after cooling.

In general, steel slag consists of $C_2O$, $MgO$, $S_2O_2$ and $F_2O$ oxides, which is in the range of about 88 percent to 90 percent. The total concentration of these oxides in the liquid milk is in the range of 88 percent - 92 percent. Although these oxides fluctuate depending on the material used, the type of fabricated steel and the state of the oven. The use of dolomite instead of lime as a flexible, highly influential on the chemical composition which gives a higher MgO content given by Mohd. Rosli Hainin et al. [57].
3.3.1.2 Chemical composition of steel slag

Table 3.1: Chemical Composition of Steel Slag

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Percentage</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Oxide (CaO)</td>
<td></td>
<td>39</td>
<td>34-43</td>
</tr>
<tr>
<td>Silicon Dioxide (SiO₂)</td>
<td></td>
<td>36</td>
<td>27-38</td>
</tr>
<tr>
<td>Aluminum Oxide (Al₂O₃)</td>
<td></td>
<td>10</td>
<td>7-12</td>
</tr>
<tr>
<td>Magnesium Oxide (MgO)</td>
<td></td>
<td>12</td>
<td>7-15</td>
</tr>
<tr>
<td>Iron (FeO or Fe₂O₃)</td>
<td></td>
<td>0.5</td>
<td>0.2-1.6</td>
</tr>
<tr>
<td>Manganese Oxide (MnO)</td>
<td></td>
<td>0.44</td>
<td>0.15-0.76</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td></td>
<td>1.4</td>
<td>1.0-1.9</td>
</tr>
</tbody>
</table>

3.3.1.3 Physical properties of Steel Slag

The physical characteristics - weight, size of particles, structural properties, etc. – vary according to the type of slag processed. Accordingly, end-use recommendations for each type differ. Processed steel slag is strong, hard, durable, dense and roughly cubical particles which make it especially suitable for use in road construction. Not all steel slag is expansive, but water quenching is the first step in weathering of steel slag which may be essential to provide a stable, non-expansive construction material.

In the cooling process, some of the lime in the slag may be “hard burnt”. The lime has a hard outer shell or surface which masks and unsound soft inner core of unhydrated lime. This lime must be saturated by water for the particle to be stable. It is important that steel slag used in construction is obtained from a producer who has a quality control program in place and minimizes the amount of unsound particles by exercising necessary quality control procedures.

Roads are subjected to static and dynamic forces, including the hostile environment such as rain, temperature, freezing and thawing. The proposed equipment must
provide adequate physical and mechanical properties to withstand and perform well. The physical and mechanical properties are given for: total value of the crushing loss angles to abrasion, the value of the overall impact, the strength, value of polished stone, water absorption and texture of the surface, pickling, specific gravity and flaking. The physical and mechanical properties of steel slag productively meet the requirements of high-class equipment. As compared to natural aggregates, it offers an ideal durability, permeability, stability and resistance to abrasion, cracking and permanent deformation.

### 3.4 Natural Soil Aggregates (Rock)

#### 3.4.1 Chemical composition of natural aggregate Rock

Soil is mainly made up of oxygen (46.7 percent), silicon (27 percent), aluminum (8.1 percent) and iron (5.0 percent). Plant nutrients like Ca, Mg, K, Na, P and S are present in the minerals and in the soil solution. O$_2$, Si, and Al occur as constituents of minerals and as oxides.

Fe occurs mainly in the form of oxides and ferromagnesian minerals. Ca occurs mainly in calcite, gypsum, apatite and dolomite. Mg is present mainly in dolomite and hornblende.

K occurs mainly in microcline and mica. P occurs as aluminum phosphate and calcium phosphate and in the organic form as phospholipids, inositol, choline, etc.

N occurs mainly in the organic form as proteins, amino acids, etc. All micronutrients like Mo, Fe, Mn, Zn, Cu, and B occur in the inorganic form.

#### 3.5 Laboratory test and research area

For finding out liquid limit, plastic limit, and plasticity index, Casagrande’s liquid limit device with grooving tool is used. For finding out the plastic limit the soil is threaded to 3 mm thick wire, for determination of shrinkage limit, Shrinkage dish is used. The sub grade soil on which the pavement is to be constructed should have
stability and strength. The stability is influenced by the soil texture, water content and density.

Any soil that is used for embankment should have required cohesion, impermeability and shear strength. When the same soil is used as the base for foundation then it should be possess’s sufficient compressive strength and shearing strength. In case of earthen dam, foundation of structure depends on the stability of the slope, shearing resistance of the soil and bearing capacity of the soil.

To find the bearing capacity of the soil values of cohesion (c) and angle of internal friction (ϕ) for the soil so the basic parameters required to be found out are c and ϕ values, shear strength and compressive strength, in case of embankments.

CBR values are required for designing the flexible pavement. Therefore, to assess the improvement in the above engineering properties of cohesive frictional soil improvement technique, compaction test, and California Bearing Ratio tests are carried out.

For finding out the values of liquid limit, the liquid limit test apparatus is used. For finding out the values of California Bearing Ratio (CBR) the California Bearing Test apparatus is used. For finding the compaction behavior of soil, i.e. Maximum Dry Density (MDD), and Optimum Moisture Content (OMC), Standard Proctor test is used.

In the laboratory, tests are conducted on the samples of soil and the steel slag as follows:

1. Grain size analysis,
2. Consistency Limits,
3. Standard Proctor Test
4. CBR test.
5. Los Angeles Abrasion test.
6. Water absorption test
7. Specific Gravity by Pycnometer
8. Impact Value test for the aggregate.
The observation tables, result and discussion on the result are discussed in the next chapter.

Results obtained for the slag from the various industries can differ to some extent, depending on the aggregate size from the manufacturer. The quality obtained depending on the steel grade i.e. as the steel is pure the slag generation is more. Therefore generation of blast furnace slag is more. From blast furnace slag, ground granulated blast furnace slag is formed, in which fine dust contents are more. One can use this slag for the agriculture use also. This will act as the enhancer for soil properties for taking more production of food in the fields. But overall production of steel slag in India is about 52 percent of overall generation of steel.

This slag has been used at various spots. In Jalna Honda show room site is totally a marshy land. In rainy season this land becomes marshy from June to December. These lands cannot be utilized for any purpose. On the experimental basis the slag is utilized for the development of the marshy land. About 50 cm thickness layer has been placed over the previous soil and the land has been used for the construction. Another example of land filling is besides Hotel Ekta in Jalna MIDC. At that site there is a very low laying area. The road surface was at about 2 meter high. This problem was solved by dumping of waste steel slag.

It has been observed that the slag which placed for land filling is not allowing the percolation of water. In field, a quarry of stone was existing. Owner used to fill this quarry for filling. After filling slag in the quarry, the springs in the well running with reduced discharge. It may be due to; the pores of stones can be filled by fine slag. If we use this slag in the construction of road, enemy of the road i.e. water will not percolate from the body of road. This will help to protect the roads.