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Laboratory Experimentation of Foundry Waste for Potential Utilization In Pavements

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Abstract: **Foundry sand is a waste material of the metal industry but can be suitably used as a construction material for civil engineering applications. Foundry industries in India are inclined to dispose of this waste in a sustainable and environment friendly manner. This paper presents a study wherein the feasibility of utilizing four types of foundry wastes as construction materials for pavement subsurface courses, was evaluated through laboratory experimentation. The laboratory study was first carried out for testing the properties of the four types of wastes. These waste properties were then compared with the traditional fill material and against the existing recommendations laid by the Indian standards. Few shortfalls were identified for the case of total replacement of the traditional material with foundry wastes; therefore blends of the fill material with foundry wastes were prepared and the researchers tried to evaluate the case of partial replacement with foundry wastes. This resulted in desirable and improved properties and therefore a blend ratio was recommended based on the laboratory results. The study indicates that a foundry waste, which is no longer recyclable in the industry, can be utilized for construction of pavements, and thus sustainably disposed.**

***Keywords*: Foundry waste, pavement, sustainable disposal, CBR**

I. INTRODUCTION

The foundry industries in India generate over several million tons of waste every year. With growing environmental awareness and concern for economic disposal, the industries are inclined to recycle these wastes through various sources. Foundry waste has great potential to be reused as a civil engineering material since their primary constituent is high quality silica.In some countries, full replacement of natural sand with foundry sand is permitted, either in loose form or encapsulated form. Numerous research studies and project demonstrations have been done worldwide to try out sustainable ways of recycling/reuse of this material. In Indian context, many organizations have encouraged use of alternative materials for construction of pavements and embankments. Although materials like flyash are tried, tested and have been allowed for partial replacement by Indian standards, foundry waste utilization for construction needs to capture the attention of Indian provisions and concerned authorities.

The overall goal of this research was to evaluate the feasibility of using foundry waste for the construction of pavement subsurface layers for the state of Gujarat, India. This research paper attempts to demonstrate the feasibility of using wastes from different foundry source channels as construction material for pavement subsurface layers (base and subbase). The study involves laboratory experimentation on foundry waste and combinations of waste and locally available natural sand to assess its engineering properties.

For a material to be used for pavement subsurface (additional subgrade and subbase) layers, it must be able to control pumping and drainage in addition to satisfying basic criteria such as density, gradation, Atterberg limits, bearing strength, shear strength, compaction, durability and swell-shrinkage parameters. Therefore, these parameters have been assessed through laboratory testing.

The results have been compared with natural fill material as well as the specifications recommended by IRC. The suitability of partial replacement with different type of foundry wastes is then judged. The results indicate that foundry waste can be effectively used as fill material when blended with natural sand without sacrifice in major requirements expected of a material to be used for subgrade, subbase and base courses of pavement. The research supports a sustainable way of large scale foundry waste disposal in an environment friendly and economic way. The practice of using foundry waste if established can be a win-win situation for the government as well as the foundry industry especially in light of economic construction of rural roads.

Sources of materials

Based on data provided by Department of Agriculture, Gujarat, there can be nine different types of soils in the state. Therefore the natural subgrade over which the pavement would be constructed can vary. For soils having poor CBR Values, it is recommended that an additional subgrade layer of approximately 0.5 m maybe constructed before laying the subbase layer.The natural soil studied and tested in this research was procured from a construction site in Ahmedabad. This has been the traditional fill material for pavement subsurface applications in the local region.

The foundry waste studied and tested herein is from steel casting industry based in Ahmedabad. The foundry uses high quality sand with bentonite and other additives for the casting mould of the metal balls. After a number of reuses, the foundry sand loses its mould properties and has to be discarded. The foundry studied does sufficient efforts to segregate the waste and collects it at various operational stages. The highest amount of waste generated in the foundry are (1) Slag Residue (non-metallic) from melting process (2) Discarded sand from rotary and sieve shake outs (3) Coarse dust from the dust extraction system and (4) Fine dust also from the dust extraction system. The generation of waste from this single foundry industry is of the order of 4500 MT/month collectively for these four types of wastes. Environment friendly and economic disposal of this waste is therefore a concern.

Properties of natural fill and foundry wastes

The current MORT&H Specification for Road & Bridge works recommend that the subgrade shall be compacted to 97 per cent of dry density achieved with heavy compaction for heavily trafficked roads. In other cases, the subgrade should be compacted to atleast 97 per cent of the standard proctor density confirming to IS 2720 Part 7. Thus it is necessary to evaluate the waste material for its Proctor density and compare with the density of traditional subgrade material. Further, it is recommended to follow guidelines from IRC 36: Recommended Practice for the construction of earthern embankments. The provisions in IRC 36 require evaluation of deleterious constituents, moisture content-dry density relation, sieve analysis/gradation result, Liquid limit and plastic limit. Therefore, these tests have been further recommended for evaluation of waste material suitability for subgrade as well as replacement of earthen embankment. In order to be used as fill for subbase, the IRC 37 Code for design of flexible pavements recommends that the CBR value for subbase should be greater than 20 % for 2 msa traffic and greater than 30 % for traffic exceeding 2 msa. It further recommends a Liquid limit of less than 25 and a Plastic limit of less than 6 for the subbase material. Therefore, the researchers further recommend the CBR Test to be done on the waste material. Additionally, the researchers found it essential to carry out the direct shear test and the unconfined compressive strength test in addition to the tests justified before.

The key properties tested for the application are (1) Particle size distribution (2) Liquid Limit and plasticity index (3) Free swell index (4) Proctor density (5) CBR Value (6) Unconfined compressive strength (7) Direct shear.

The properties of the natural fill material available in Ahmedabad and the four types of foundry wastes (Slag Residue, Discarded Sand, Coarse Dust, Fine Dust) are presented in Table 1.

Table 1: Properties of natural fill and foundry wastes

Soil and Material Values						
Tests	Density (gm/cc)	LL	Free Swell Index	CBR	MDD	OMC
AL	2.68	22.7	6.67	5.79	1.89	9.56
SR	2.82	29.5	12.5	17.27	1.89	13.48
DS	2.69	32.7	78.57	16.98	1.77	12.07
CD	2.68	34	12.5	6.42	1.69	13.66
FD	2.58	43.5	-15.38	3.07	1.48	21.42

Observations on the properties of the foundry wastes

The case of slag residue

Following observations could be made for the slag residue when compared to the natural sand:

(a) The density of the slag residue is about the same as that of the natural fill.
(b) The liquid limit for the slag residue is typically higher than recommendable values but is close to that of natural sand.
(c) The slag residue is non plastic in nature.
(d) The slag residue does not swell much; it is well within required swell parameters.
(e) The CBR value of the slag residue is higher than that of the local soil and this is seen as a promising attribute.
(f) The maximum dry density of the slag residue obtained from Procter test is same as the local soil but requires slightly more water content to achieve this MDD.

The case of discarded sand

Following observations could be made for the discarded sand when compared to the natural sand:

(g) The density of the discarded sand is about the same as that of the natural fill.
(h) The liquid limit for the discarded sand is typically higher than recommendable values.
(i) The discarded sand is non plastic in nature.
(j) The discarded sandhas high swelling parameters.
(k) The CBR value of the discarded sand is higher than that of the local soil and this is seen as a promising attribute.
(l) The maximum dry density of the discarded sand obtained from Procter test is same as the local soil but requires slightly more water content to achieve this MDD.

The case of coarse dust
Following observations could be made for the coarse dust when compared to the natural sand:
(a) The density of the coarse dust is about the same as that of the natural fill.
(b) The liquid limit for the coarse dust is typically higher than recommendable values.
(c) The coarse dust is non plastic in nature.
(d) The coarse dust does not swell much; it is well within required swell parameters.
(e) The CBR value of the discarded sand is comparable to that of the local soil and this is seen as a promising attribute.
(f) The maximum dry density of the discarded sand obtained from Procter test is same as the local soil but requires slightly more water content to achieve this MDD.

The case of fine dust
Following observations could be made for the fine dust when compared to the natural sand:
(a) The density of the fine dust is slightly less than that of the natural fill.
(b) The liquid limit for the fine dust is much higher than recommendable values.
(c) The fine dust is non plastic in nature.
(d) The fine dust does not swell much; but it actually shrinks slightly when tested.
(e) The CBR value of the discarded sand is very less and it may not be helpful for strength improvement.
(f) The maximum dry density of the discarded sand obtained from Procter test is less than that of the local soil and requires more water content to achieve this MDD.

Properties of blends
It was observed that full replacement of the natural fill may not be the most viable option due to reasons of high compaction effort, excessive liquid limit and undesirable swell parameters. However, replacement of natural fill with the waste also improved certain strength properties (especially CBR) and therefore blending of the material was recommended for making the best of both materials. Consequently, each of the four wastes was blended with the natural material in different proportions and the behaviour of the blends was then judged against the acceptability criteria.
Blending of each waste was done with the local soil (AL) in proportions of 20 %, 40 %, 60 % and 80 % of waste. The following tables indicate the properties of the blended samples.
The case of slag residue blends

Table 2: Properties of slag residue blends with the local soil

AL + SR						
Tests	Specific Gravity	LL	Free Swell Index	CBR	MDD	OMC
AL 80% + SR 20%	2.36	25.4	7.14	14.36	1.92	10.2
AL 60% + SR 40%	2.67	26.1	12.5	15.77	1.92	10.46
AL 40% + SR 60%	2.68	30.2	0	15.13	1.89	11.19
AL 20% + SR 80%	2.57	30.8	0	13.14	1.87	11.24

Slag residue was identified to have no major concerns if used as a replacement of traditional fill. A small concern was striking the right balance between the advantages in property of CBR as opposed to increase in Liquid limit. As much as 80 % of the slag residue may be added without significant violation of the liquid limit. It is noted again that the material has a promising CBR value.

The case of discarded sand blends

Table 3: Properties of discarded sandblends with the local soil

AL + DS						
Tests	Specific Gravity	LL	Free Swell Index	CBR	MDD	OMC
AL 80% + DS 20%	2.73	23.8	16.67	9.83	1.9	10.72
AL 60% + DS 40%	2.66	23.5	13.33	10.12	1.9	10.09
AL 40% + DS 60%	2.71	26.3	25	17.66	1.87	11.71
AL 20% + DS 80%	2.57	27.3	26.67	10.85	1.83	11.8

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The major issue identified with the discarded sand material was the swell parameter.It is however, observed that blending it with about 40-60 % of the local soil can control the swell considerably and also gives better CBR results than the local soil by itself. It must be noted that the blend also has a controlled liquid limit. Thus, the researchers recommend that a 50-50 blend of the discarded sand with natural local soil may be used in practice for satisfactory results. This can be in form of alternate layers of the material laid on construction site.
The case of coarse dust blends

Table 4: Properties of coarse dust blends with the local soil

AL + CD						
Tests	Specific Gravity	LL	Free Swell Index	CBR	MDD	OMC
AL 80% + CD 20%	2.36	36	6.67	7.45	1.83	11.42
AL 60% + CD 40%	3.2	28.5	6.67	10.56	1.8	11.84
AL 40% + CD 60%	2.77	31.2	6.25	15.72	1.76	13.22
AL 20% + CD 80%	2.87	32.7	18.75	9.44	1.73	13.45

The major issue identified with the coarse dust material was the swell parameter. It is however, observed that blending it with about 40-60 % of the local soil can control the swell considerably and also gives better CBR results than the local soil by itself. It must be noted that the blend also has a controlled liquid limit. Thus, the researchers recommend that a 50-50 blend of the discarded sand with natural local soil may be used in practice for satisfactory results. This can be in form of alternate layers of the material laid on construction site.
The case of fine dust blends

Table 5: Properties of fine dust blends with the local soil

AL + FD						
Tests	Specific Gravity	LL	Free Swell Index	CBR	MDD	OMC
AL 80% + FD 20%	2.36	24.9	-15.79	11.87	1.86	11.71
AL 60% + FD 40%	2.74	30	-13.04	13.33	1.74	14.62
AL 40% + FD 60%	2.75	35.3	-20.69	4.18	1.67	16.13
AL 20% + FD 80%	2.75	40	-23.53	0.24	1.54	19.13

The major issues identified with the fine dust material were the shrinkage and high liquid limit. Based on the results, not more than 20 % of fine dust is recommended for use even as blend with the local material.

II. CONCLUSIONS

Based on the results of laboratory testing of foundry sand wastes from different channels and blends of these wastes with local soil found in Ahmedabad, the researchers recommend the use of slag residue for pavement subbase course and artificial subgrade wherever required. The researchers recommend the use of discarded sand and coarse dust up to 50 % in form of alternate layers with natural fill material. The researchers do not recommend the fine dust highly for the pavement subsurface layers; however it may be explored as 20 % addition to natural soil if cost benefits are anticipated. The researchers further recommend reusing the foundry waste in various proportions mentioned for pavement subsurface applications for benefits such as environment friendly disposal, cost savings and overall sustainability benefits. Further, the use in embankments, structural fills and block making may be explored with this material for civil engineering purpose.

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