Abstract—The primary source of hazardous wastes at an automotive manufacturing plant is the painting process, and the major waste fraction is paint sludge. Paint sludge is a hazardous waste that poses serious risk for both health and environment – yet they often cannot be avoided in the process industry. The amount of the paint sludge generated increases every year with the worldwide increase in the automotive production.

In fact, industrial ‘paint sludge’ is a waste, which cannot be prevented from getting generated, because when any product or component is finished by spray painting with liquid solvent based paint, 20 to 60 per cent paint goes as off-spray waste and gets collected outside the paint-shop in a sludge pit with the help of regularly flowing water stream through the paint booth, either in front of the painter as a water screen or under the floor grating of the paint booth.

This collected off-sprayed paint churned and mixed with water along with some detackifying chemicals, known as booth additives, is known as ‘paint sludge’.

Major routes for the disposal of the paint sludge’s are incineration as hazardous waste or combustion at cement kilns. Incineration and co-incineration – both are non-eco-friendly processes, and are having some or the other pollutant generation either by way of emission or as residual wastes.

Recycling of paint sludge is completely environmental friendly technology.

There have been many attempts, to use paint sludge for creating various useful byproducts. Paint sludge can be reused as an ingredient in a productive process or recovery of a reusable product sustainably. Processing of paint sludge is time consuming and costly. Accordingly, there is need for a simple process that effectively uses all of the paint sludge solids generated by a paint booth facility.

In this paper discuss the process to utilize the liquid paint sludge directly as a component in concrete and cement type building materials.

Keywords: Automotive; building materials; Cement kiln; paint sludge; Spray booth; Solvent-based; Water-based

I. INTRODUCTION

Industrial painting by spraying, generate waste due to off-spray. This off sprayed paint washed with the help of circulating/running water gets collected in a pit. This mixture of water with off sprayed paint is known as "PAINT SLUDGE". Paint spray booths for vehicles are typically 100–300 feet in length and usually contain many robotic and manual spray zones. The temperature and humidity are rigorously controlled in these systems. As items are painted in these booths, a certain amount of paint does not contact the article being painted and forms a fine mist of paint in the air space surrounding the article. This paint must be removed from the air. To accomplish this, the contaminated air is pulled through the paint spray booth by exhaust fans. A curtain of circulating water is maintained across the path of the air in such a way that the air must pass through the water curtain to reach the exhaust fans. As the air passes through the water curtain, the paint mist is “scrubbed” from the air and carried to a sump basin (sludge pit), usually located below the paint spray booth. In this area, the
paint particles are separated from the water so that the water may be recycled and the paint particles disposed of as paint sludge.

In order to assist in the removal of the oversprayed paint from the air and to provide efficient operation of the down-draft, water-washed paint spray booths utilize paint detackifying chemical agents[1]. The detackification products are commonly introduced into the water that is recirculated in the paint spray booth system. The first purpose is to render the paint non-tacky so it does not stick to the booth equipment and foul the paint system. The second purpose is to efficiently collect the paint solids that were sprayed into the system and remove them from the water for disposal.

This semi-solid lumpy material is classified as a hazardous waste – because if it is thrown freely anywhere on the ground it deteriorates the fertility of soil badly, and by way of leachates generated by it – the ground water gets polluted. It is not only harmful for the agricultural land, but also it destroys the flora and fauna of the area wherever it is thrown or disposed off.

As far as ‘paint sludge’ generation is concerned – every year India alone generates about 65,000 K.Ltrs. of industrial ‘paint sludge,’ out of which about 40,000 K.Ltrs. is generated by the organised sector that can be collected for recycling.

Unfortunately, the Govt. of India has allowed to incinerate and co-incinerate the ‘paint sludge’ by industrial incinerators and in cement kilns respectively.

According to statutory rules about paint sludge is classified as hazardous industrial waste under the hazardous waste rules, 1989 as amended up to may 2003 (section –21.1) and under the orders promulgated by honorable supreme court of India, in slp (c) no. 16175 / 1997 and c.a. no. 7660 / 1997, its removal out of the premises of industrial unit producing it is prohibited, this can only be transported to a govt. approved disposal site – through a govt. licensed transporter – with due permission from state p.c.b.

Disposal Methods for Sludge Presently Being Followed.

- Incineration by industrial incinerators.
- Disposal of sludge to the government approved hazardous waste disposal sites, after due testing and treatment by payment of gate fee.

Problems faced by the industries in compliance to above :-

1. Non availability of govt. approved disposal sites
2. Shortage of govt. licensed transporters
3. Exorbitant transportation and disposal cost
4. incineration consumes natural resources like fuel, adding to the cost, that too with environmental pollution by way of emission, and remnant ash.

Alternative Solutions: Recycling

"The policy document should emphasize a commitment to the recycling of wastes and materials, and propose incentives for encouraging and supporting recycling. Industries must be given a clear message that they must show concrete and tangible results as far as prevention and reduction of wastes are concerned.

1. Can develop the primers for tractor and motorcycle parts.
2. Blending the ‘paint sludge’ with the road construction bitumen that will improve the water resistance of the bituminised road, and hence will increase the life of the bituminous road and will keep them free from potholes.
3. Use of paint sludge in producing building material, Bricks preparation.

II. LITERATURE REVIEW

Several attempts have been made over the last twenty years to utilize paint sludge for producing various useful byproducts rather than to dispose of it in a landfill or to incinerate. These attempts have particularly involved the extraction of valuable materials taking advantage of pyrolytic processes and the reuse of the treated waste in the sealant and paint industry and in the production of building materials.

Kim and Coauthors (1996) [2] describe a process for pyrolyzing paint sludge (mixed with potassium hydroxide) at 600°C to prepare activated carbon. This activated carbon is a high surface-area char containing inorganic oxides which is suggested to be useful to adsorb volatile compounds in manufacturing plants.


The first attempt for using paint sludge in the sealant industry is presented in US Patent No 4,980,030 (Johnson and Slater, 1990)[6] discussed a method for treating waste paint sludge including water, uncured resin and liquid hydrocarbons.

A similar process is shown in US Patent 5,087,375 (Weinwurm, 1992) [7] which discloses a method of heating and calcining the paint sludge to form a product which may be used as filler for sealants. US Patents 5,922,834 (Gerace et al., 1999 a)[8] show a method of treating paint sludge, that removes a substantial portion of water and solvent by drying the sludge without curing the polymer. Patent 5,573,587 (St. Louis, 1996) [9] provides a process for producing building materials (concrete, mortar or asphalt) from some water-based paint sludge from paint booth operations.

Invention presented in US Patent 7,128,780 (Matheson et al., 1996)[10] provide a process for directly using liquid paint sludge as an integral component in the production of cement and concrete-type building materials, thus providing an efficient method for the recycling of paint sludge. The recent process which aims to treat paint sludge relates to a composition for the conversion of the waste into a reusable paint. This process is summarized in patent WO 2007 072502 (Bhatia et al., 2007).[11]

In this paper author have discussed the process to utilize the liquid paint sludge directly as a component in concrete and cement type building materials.

III. METHODOLOGY AND PROCESS

A process for producing building materials, such as asphalt, cement, concrete, mortar, or plaster board from liquid paint sludge containing water and paint solids produced from overspray in commercial paint booth operations in this way adding the liquid paint sludge as the hydrating agent directly to the building material mix.

The present study provides a process for directly using liquid paint sludge containing water and paint solids produced from paint booth operations as an integral component in the production of cement and concrete type building materials, while providing an efficient method for the recycling of paint sludge.
sludge. In this way saves processing time and comprises very few steps, and avoids the need for extensive processing and sludge treatment.

The process of using the paint sludge and producing building materials there from comprises:
(a) mixing the liquid paint sludge with one or more materials used to produce building materials, such as cement mix or concrete mix or portions thereof; and
(b) allowing the mixture to cure, thereby producing a building material therefrom.

The benefit of this process is that paint sludge is used as the hydrating material in the building material. Preferably, the paint sludge is the sole source of hydrating material. Optionally, however, additional water can be added to provide the water to building material ratio desired.

DETAILED DESCRIPTION OF THE PROCESS: - The term “liquid paint sludge” as used herein means raw unprocessed paint sludge or possibly only moderately concentrated or moderately diluted paint sludge generated from paint booth operations. Waste paint sludge is a complex material and is different from most other waste sludge. Such sludge typically includes volatile organic compounds (“VOC’s”), such as thinner and solvents, uncured polymeric paint resins that can “cure,” that is cross-link, crosslinkers, and inorganic and organic pigments. The study is particularly directed to using raw paint sludge generated from automotive body or component spray painting operations.

Paint sludge is typically produced from overspray from spray painting an object such as an automobile in a paint booth and from other waste streams. Overspray paint sludge, in particular, is collected in troughs beneath the paint booth containing circulating water. This liquid sludge generally includes components captured from the application of various automotive finishes, such as primers, pigmented basecoats and clearcoats, each of which can be water borne or solvent borne finishes. Liquid paint sludge therefore consists of water, collected paint and booth chemicals, which serve to disperse the paint particles in the water stream.

Examples of well known basic building material ingredients that can be mixed with the paint sludge include Portland cement, cement mix, mortar mix, concrete mix, plaster mix, and the like. Portland cement, for instance, is a basic ingredient of concrete. It is made up of a controlled chemical combination of calcium, silicon, aluminum, iron and small amounts of other ingredients to which gypsum is added in the final grinding process to regulate the setting time of the cement. Lime and silica make up about 85% of the mass. Common among the materials used in its manufacture are limestone, shells, and chalk or marl combined with shale, clay, slate or blast furnace slag, silica sand, and iron ore. These materials are coarsely crushed, heated to above 1400° C. to convert calcium carbonate present to calcium oxide and calcium silicate and then ground to produce a fine gray powder. Hydration or addition of water, to Portland cement converts the calcium oxide to calcium hydroxide which is the active curing material in concrete through its reaction with carbon dioxide to produce calcium carbonate. It has been found that paint sludge can be used as the principal source of water for Portland cement, and preferably as the only source.

Cement mix is a dry blend of quicklime and sand which is used as a building material. Quicklime is chemically known as calcium oxide and is produced by heating limestone or equivalent material above 1400° C. Addition of water hydrates the calcium oxide and yields a material that is formable and cures to a hard durable surface. In the present invention, paint sludge can be used as the principal source of water for cement mix, and preferably as the only source.

Mortar mix is a dry blend of Portland cement and sand. Water is added to the mix to produce a workable material that is used to bond preformed building materials such as brick and concrete
blocks. Mortar also seals the structure against moisture and air penetration. The most important qualities of mortar are bond strength and durability. In this way again paint sludge can be used as the principal source of water for mortar mix, and preferably as the only source.

Concrete mix is a dry blend of Portland cement, sand and aggregate such as gravel or crushed stone. Water is added to the dry mix to form a workable building material. Paint sludge can be used as the principal source of water for concrete mix, and preferably as the only source in concrete as well. Concrete can be used to manufacture preformed building material such as concrete block or pre-stressed concrete, or used in fluid form to fill forms or molds.

Plaster mix is the dry form of calcined gypsum rock. The chemical composition of gypsum is $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$—calcium sulfate dihydrate which when heated above 100° C. loses water of hydration to give calcium sulfate hemi-hydrate, commonly called Plaster of Paris, which after further processing is suitable for use in commercial applications. In use, water is added to the plaster mix to form a paste which can be worked. Paint sludge can be used as the principal source of water for plaster mix, and preferably as the only source. A principal use of plaster is to make plasterboard, a pre-formed building material.

Asphalt is the material left in the oil refinery process after other ingredients (gasoline, kerosene, oil, etc.) have been removed. This material is blended with aggregate and mineral filler to produce building material suitable for such uses as paving and roofing. Asphalt can be used in hot form or converted to an emulsified form with a slurry consistency where cold application is desired. Paint sludge can be used as the principal source of water for formation of emulsion asphalt, and preferably as the only source. Paint sludge contains emulsifiers that may reduce or eliminate the need for additional emulsifiers.

Building materials of very high quality are produced by the above method. Other beneficial qualities resulting from this study are described below. Building materials produced by the foregoing method can lessen the amount of added plasticizers, air entrainment agents, and similar chemicals commonly employed in the production of chemical admixtures for building materials intended for special purposes. The exothermic heat of hydration reactions which accompany the curing of cement based products must often be taken into consideration, as for example within very massive structures. The present use of paint sludge introduces novel components into the curing mixture that may moderate the rate of hydration and thus the exotherm.

The usable temperature range for pouring cement or concrete and other cement based compositions is ordinarily set by the conditions dictated by the environment during construction. The time to achieve both workable properties and ultimate properties is an important factor. This research may particularly extend the workability below the freezing point of water. Although paint sludge is quite fluid, it beneficially has a viscosity higher than water may result in easier mixing of the cement or concrete mix. ASTM D-2196 specifying the Brookfield instrument is typically used to determine viscosity. While the desired viscosity will vary with the selected components, viscosity generally will be in the range of 2 to 500 centipoise, preferably 2 to 100 centipoise, to achieve improved mixing.

In summary, the main advantage of this research work is that it teaches the use of paint sludge directly as the hydrating source, preferably the only source of hydration, in the building material, which avoids the need for extensive prior processing of the paint sludge and conversion into powder before it is used to produce building materials.
The following example illustrates the invention. All parts and percentages are on a weight basis unless otherwise indicated.

EXAMPLES :- The following building materials, one using paint sludge and one using city water, were prepared, molded into cylinders, and then the properties of these compositions were compared.[13]

**Example 1 Comparative Example**

A full bag (30 kg) of concrete mix was added to an electric cement mixer and dry blended for 1 minute. 15 kg of the blended concrete mix was weighed into a plastic pail, and 1.5 kg city water, that had been tempered to 76° F., was weighed into a container. The pail of concrete mix (15 kg) was added to a clean dry mixer, the motor was turned on and approximately ¾ of the pre-measured city water was added and allowed to mix for 2 minutes. The remainder of the water was added and allowed to mix for 1 minute.

The mixed concrete was scooped from the mixer using a plastic cup and poured into a 4"×8", cylindrical mold. The mold was filled ⅓ and then rodded and tapped on the side to release air. This was repeated at ⅔ full and full. A straight edge was used in a sawing action to produce a flat bottom.

Three test cylinders (A, B, C) were produced in the same fashion in conformity with ASTM C31-84.[14]

**Example 2 Paint Sludge Example**

Concrete was made in an identical fashion to example 1 except that the city water was replaced with paint booth sludge taken from a commercial automotive assembly plant.

**Curing and Testing**

All samples were cured and tested in the same fashion. Initial curing was at 68°–80° F. with mold lids securely closed followed by 28 days at 68°–80° F. with the lids removed. Following cure the concrete cylinders were tested according to ASTM C39-83B.[15]

The test results are provided below.

<table>
<thead>
<tr>
<th>Specimen Name</th>
<th>Maximum Force</th>
<th>Corresponding Displacement</th>
<th>Maximum Stress</th>
<th>Corresponding Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>−57154</td>
<td>0.0954</td>
<td>4,548</td>
<td>0.0626</td>
</tr>
<tr>
<td>1B</td>
<td>−61860</td>
<td>−0.380</td>
<td>4,923</td>
<td>0.0531</td>
</tr>
<tr>
<td>1C</td>
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<td>0.0644</td>
<td>4,709</td>
<td>0.0566</td>
</tr>
<tr>
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<td></td>
<td>4,727</td>
<td>0.0574</td>
</tr>
<tr>
<td>Avg. Water</td>
<td></td>
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<tr>
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<tr>
<td>Avg. Sludge</td>
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<td></td>
<td>4,444</td>
<td>0.0545</td>
</tr>
</tbody>
</table>

The above results show that concrete made from city water and concrete made from paint sludge have comparable compressive strength and strain results, which are both well above ASTM strength and strain requirements for concrete.
IV. CONCLUSION

By innovative process, we convert paint sludge to an industrially usable building material without any compromise in properties, strength and strain. Recycling the ‘paint sludge’ is also an economically viable proposal as it saves the cost of incinerating for the industries disposing it off by incineration. They will also save the cost of disposal for the remnant ash, which is also a hazardous waste and needs to be disposed off at TSDF site. And hence by adoption of this technology, user will get the following advantages:

1. 1.1 to 2.2 ton of fuel is required for the incineration of 1 ton of waste sludge. Around 800-900 ton of natural fuel would be saved annually by recycling waste sludge.
2. Recycling of paint sludge saves 1.1 – 1.2 tons of virgin raw materials of our nation, for every ton of paint sludge (dried) recycled.
3. Reduction in green house emissions.
4. Recycled primer cheaper than virgin primer.
5. Cost savings on account of disposal cost
   a) Approx. savings on disposal cost (in Rs.Lakh) = 100
   b) Approx. saving on material cost (in Rs.Lakh) = 36
6. User industry will get relieved from all worries of hazardous waste handling and disposal.
7. In this way industry will contribute towards environmental protection of our nation.

Hence we can conclude that above process for producing building materials from raw paint sludge is technically feasible, economically sound and ecofriendly option to environmental protection.

REFERENCES