Current Advances in Civil Engineering Research

Volume - 2

<u>Chief Editor</u>

Dr. N. Sudharsan
Associate Professor, Vidya Jyothi Institute of Technology, Hyderabad, Telangana, India

Integrated Publications
New Delhi

Published By: Integrated Publications

Integrated Publications
H. No. - 3 Pocket - H34, Sector - 3,
Rohini, Delhi-110085, India

Chief Editor: Dr. N. Sudharsan

Publication Year: 2022

Pages: 68

ISBN:

Book DOI: https://doi.org/

Price: ₹ 701/-

Contents

Chapter - 1

Fractional Substitution of Bitumen by Waste Plastic and Polypropylene in Road Construction

Authors

C. Balakrishna
Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

L.M. Varun
Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

T. Ramprasanna Kumar Reddy
Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

Vempati Ravindra
Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

Chapter - 1

Fractional Substitution of Bitumen by Waste Plastic and Polypropylene in Road Construction

C. Balakrishna, L.M. Varun, T. Ramprasanna Kumar Reddy and Vempati Ravindra

Abstract

In this work some of plastic waste materials which can reuse by various methods and used in road construction. The discussed materials have many advantages over conventional/traditional materials and methods. Now a Days disposal of plastic waste has became a problem of great concern for environmental engineers due its non-biodegradable characteristics and hazard. Bitumen is currently one among the foremost widely used binding materials in road pavement. The explanations thanks to which bitumen is usually used as a binding material are its excellent binding characteristics, waterproofing properties and low cost as compared to other binders Bitumen is currently one among the foremost widely used Binding Material in Road Pavement. This project will conduct a study on recycling plastic waste and blending it with bitumen to get roads in India and compare with the environmental and economic conditions. Some of these Materials are relatively Cheaper compared to other Binders and Materials which provides more strength and Durability as compared to Conventional Road Construction. This Study presents Results of the Waste Plastic and Polypropylene which are used as a Modifier by an amount 2%, 4%, 6%, 8%, 10% by its Weight of Bitumen in making bituminous mixture for pavement applications. When waste plastic is mixed with bitumen it will come up with useful information and creating awareness amongst the learner in the industry regarding waste material and also increases its water Resistivity, Capacity and Stability. Marshal Stability test is taken into account to stimulate with field condition.

Keywords: Waste plastic, aggregate, bitumen, polypropylene.

1. Introduction

The amount of waste plastics and polypropylene are produce in day today life. The most threat to the environment is that the disposal of waste plastic. During a highway, the potholes and corrugation is that the most problem. Disposal of this waste plastic is that the challenging problem altogether over the world. They either get mixed with municipal solid waste or disposed over acreage. Various attempts are made for the recycling and reuse of waste plastic like polythene covers, plastic bags, plastic bottles, etc., the rapid increase in high traffic intensity additionally to significant alteration in daily and seasonal temperature, demand qualitatively best road characteristic. Especially in under developing countries where proper maintenance of road networks is difficult due to lack of funds, heavy control while laying and effective machinery. These polymers besides being costly aren't easily available that's why many research are performed for modification of bitumen by using waste polymers. The polymers used for modification of bitumen for paving purposes are generally styrene-butadiene styrene, copolymer styrene-butadiene, rubber latex, ethylene vinyl acetate, copolymer PVC, polypropylene etc. The use of waste plastic improves the abrasion & slip resistance of asphalt pavements. In India, because of hot and really humid climate, plastic pavements of greatest advantage. In order absorb the smoke from the vehicles; titanium di-oxide are often used. It also enhances the mechanical properties of the plastic, leading to higher strength and high resistance.

Objectives

1) To increase the durability of Pavement.
2) To increase the flow value.
3) To reduce the worth of the materials (bitumen).
4) It are getting to be economical since waste like plastic is used.
5) It reduce soil Fertility, biodegradable condition.
6) To use the waste plastic as useful binding material.

2. Materials used

Plastic

Plastic may be a material consisting of any of a good range of synthetic or semi-synthetic organics that are malleable and may be moulded into solid objects of diverse shapes. Plastics are generally organic polymers of high molecular mass, but they often contain other substances. They're usually synthetic, most ordinarily derived from petrochemicals, but many are partially natural. Plasticity is that the general property of all materials that are ready to irreversibly deform without breaking, but this happens to such a degree with this class of mouldable polymers that their name is a stress on this ability.

Low density poly ethylene (LDPE)

Low-density polyethylene (LDPE) may be a thermoplastic made up of the monomer ethylene. It had been the primary grade of polyethylene, produced in 1933 by Imperial Chemical Industries (ICI) using a high process via radical polymerization. Its manufacture employs an equivalent method today. The EPA evaluate 3.3.7% of LDPE (recycling number 4) is recycled. Despite competition from more modern polymers, LDPE continues to be a crucial plastic grade. In 2013 the worldwide LDPE market extend to a volume of about US$33 billion.

Fine aggregates

Fine aggregate (Sand) may be a present granular material composed of finely divided rock and mineral particles. It's describe by size, being finer than gravel and coarser than silt. Sand also can ask a textural class of soil or soil type; i.e., a soil containing quite 85% sand-sized particles (by mass).

Coarse aggregates

Construction aggregate (coarse aggregate), or just “aggregate”, may be a broad category of coarse particulate material utilized in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates.

Bituminous material

Bituminous materials are one among the oldest and most generally used construction materials. While their components are obtained from finite resources, these materials have long been referred to as sustainable products thanks to their capacity to increase their serviceable lives through reclaim, reuse and/or the recycling processes. This part presents holistic aspects on the sustainability of bituminous materials, including their sources, processes, productions, standards, designs, good practices, and preservative maintenance.

3. Experimental investigation

Tests on aggregates

1) Aggregate Impact Value Test
2) Los Angles Abrasion Test
3) Aggregate Crushing Test
4) Specific Gravity And Water Absorption Test

Tests on bituminious materials

1) Penitration Test on Bituminious Material
2) Ductility Test on Bituminous Material
3) Softening Point Test
4) Flash and Fire Point Test
5) Marshall Stability Test on Bitumen

4. Marshall stability test on bitumen

This Test is used to regulate the Marshall Stability of Bituminous Mixture of ASTM D 6927. This test is that the Marshall Stability is the Resistance to Plastic Flow of Cylindrical Specimens of a Bituminous Mixtures loaded on the Lateral Surface. It is the Loading Capacity of the mix at 60 deg centigrade and measured in kg.

The Total Weight of the mixed Specimen should be 1200gr.

Marshal test procedure

- Specimens are heated to 60 ± 1 °C in a water bath for 30 - 40 minutes or in an oven for minimum of 2 hours.
- The specimens are separated from the water bath or oven and place in lower segment of the breaking head. The upper portion of the breaking head of the specimen is placed in position and the complete assembly is placed in position on the testing machine.
- The flow meter is placed over one of the post and is adjust to read zero.
- Load is applied at a rate of 50 mm per minute until the maximum load reading is secured.
- The maximum load reading in Newton is noticed. At the same immediately the flow as recorded on the flow meter in units of mm was also noted.

Marshall mix design

Properties of mix

The properties that are of interest involve the theoretical specific gravity Gt, the bulk specific gravity of the mix Gm, percent air voids Vv, percent volume of bitumen Vb, percent void is mixed aggregate VMA and percent voids filled with bitumen VFB. To make out these calculation a phase diagram is given.

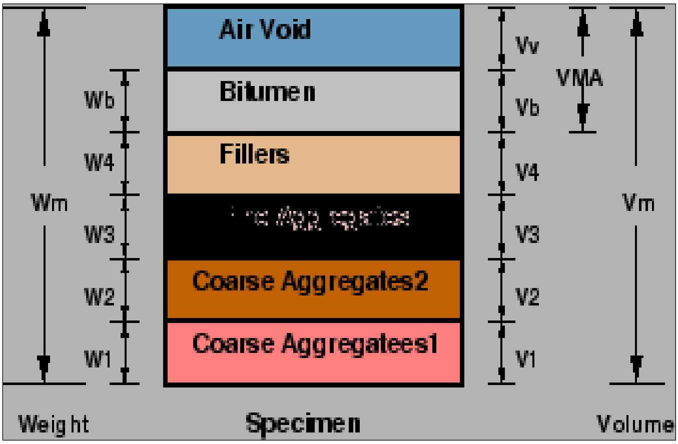

Fig: Phase Diagram of a Bitumenios mix

$$G_t = \frac{W_1 + W_2 + W_3 + W_b}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_b}{G_b}} \tag{1}$$

Bulk specific gravity of mix [G_m]

The bulk specific gravity or the actual specific gravity of the mix G_m is the specific gravity considering air voids and it is found out by

$$G_m = \frac{W_m}{W_m - W_w} \tag{2}$$

Air voids percent $V_{v:}$

Air voids V_v is the percent of air voids by volume in the specimen and it is given by

$$V_v = \frac{(G_t - G_m)100}{G_t} \tag{3}$$

Percent volume of bitumen V_b

The volume of bitumen V_b is the percent of volume of bitumen to the total volume and it is given by

$$V_b = \frac{\frac{W_b}{G_b}}{\frac{W_1+W_2+W_3+W_b}{G_m}} \tag{4}$$

Voids in mineral aggregate VMA

Voids in mineral aggregate VMA is the volume of voids in the aggregates, and it is the sum of air voids and volume of bitumen, and is calculated from

$$VMA = V_v + V_b \tag{5}$$

Voids filled with bitumen VFB

Voids filled with bitumen VFB is the voids in the mineral aggregate frame work filled with the bitumen, andit is calculated as:

$$VFB = \frac{V_b \times 100}{VMA} \tag{6}$$

Determine marshall stability and flow

Marshall stability of a test specimen is the maximum load essential to produce failure when the specimen is preheated to a prescribed temperature placed in a special test head and the load is put in at a constant strain (5 cm per minute). While the stability test is in advance dial gauge is used to measure the vertical deformation of the specimen. The deformation at the failure point intimate in units of 0.25 mm is called the Marshall flow value of the specimen.

5. Discussion

Tests on aggregates

1) Aggregate impact value test

For determination of the aggregate impact value of coarse aggregate, which passes through 12.5 mm, IS sieve and retained on 10 mm IS sieve.

Discussion

Aggregates are worn for wearing course, the impact value shouldn’t be exceed 30 percent. For bituminous macadam the utmost permissible value is 35 percent. For Water bound macadam base courses the utmost permissible value defined by IRC is 40 percent.

2) Los angles abrasion test

Abrasion test is fetch out to test the hardness property of aggregates and to decide whether they are suitable for different pavement construction works. Los Angeles abrasion test is a favour (preferred) one for carrying out the hardness property and has been standardized in India (IS: 2386 part-IV).

Discussion

An utmost value of 40 percent is authorized for WBM base course in Indian conditions. For bituminous concrete, a utmost value of 35 percent is specified.

3) Aggregate crushing test

One of the model in which pavement material can fail is by squash (crushing) under compressive stress. A test is systematize by IS: 2386 part-IV and used to determine the crushing strength of aggregates. The aggregate squash (crushing) value gives a relative measure of resistance to crushing under gradually applied crushing load.

Discussion

A value less than 10 signifies an exceptionally strong aggregate while above 35 would normally be considered as weak aggregates.

4) Specific gravity and water absorption test

The specific gravity and water absorption of aggregates are considerable properties that are required for the design of concrete and bituminous mixes. The specific gravity of a solid is in the ratio of its mass to that of an equal volume of distilled water at a identified (specified) temperature.

Discussion

The specific gravity of aggregates usually worn in road construction ranges from about 2.5 to 2.9. Water absorption values ranges from 0.1 to about 2.0 percent for aggregates commonly worn in road surfacing.

Tests on bitumen

1) Penitration test on bituminious material

It measures the hardness or softness of bitumen by estimate the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds. BIS had standardized the equipment and test procedure.

Discussion

When the modifiers are mixed with Bitumen the penetration values Persist Decreasing compared with Conventional. Due to Decreasing of Values, its Signified that the penetrated values for Modifiers indicates that there will be a improvement in the Temperature Liability Resistant Characteristics in road Constructions.

It may be noted that penetration value is largely determine by any inaccuracy with regards to pouring temperature, size of the needle, weight placed on the needle and the test temperature.

In hot climates, a lower penetration grade is (Favoured) preferred.

2) Ductility test on bituminous material

Ductility is the property of bitumen that permits it to go through great deformation or elongation. Ductility is describe as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking.

Discussion

As, we know that the Ductility value should not be less than 50cm as per Standards and References Given by IS. But, the modifiers in the bituminous materials percentage Values are variously decreasing in Both Waste Plastic and LDPE (Polypropylene) in the Ductility Test. So, as the Ductility Values Decreases with increasing in modifiers Percentages it should not be used in Road Constructions, but it can be used as a Filler Materials in Less Percentage for filling and Healing both of Cracks and Joints.

The ductility value gets pretentious by factors such as pouring temperature, test temperature, rate of pulling etc.

A minimum ductility value of 75 cm has been specified by the BIS.

3) Softening point test

Softening point indicates the temperature at which the bitumen attains a particular degree of softening under the specified condition of test.

Discussion

As, the modifiers Percentages Increases in the Addition of Bituminous material, the Softening point Values also Increasing Parallelly, by this Result we can Suggest that the modifiers with bitumen can be mixed with lower Percentage which can be used for Road Constructions.

In generally, higher softening point indicates lower temperature susceptibility and is preferred in hot climates.

4) Flash and fire point test

Flash and Fire point test is to manage on bitumen to know the safe mixing and application temperature values of particular bitumen grade.

Discussion

As, Modifiers Percentages in the Bitumen increases the Temperature Values for Flash Point and Fire Pont also Increasing Rapidly. So, Modifiers can be used in the Road Constructions, Where the Temperature Increases Rapidly.

5) Marshall stability test on bitumen

Marshal test is extensively used in procedure test programs for the paving jobs. The stability of the mix is reported as a maximum (utmost) load carried by a compacted specimen at a standard test temperature of 600 °C. The flow is measured as the distortion in units of 0.25 mm between no load and maximum load carried by the specimen during throughout stability test (flow value can also be measured by deformation units of 0.1 mm). This test aims to get the optimum binder content for the aggregate mix type and traffic intensity. This test will helps us to draw Marshall Stability vs. % bitumen.

Discussion

As the additive content increases in the Bitumen the Stability Rate also Increases initially and when it reaches the Maximum Value the percent starts Decreasing. The addition of LDPE (polypropylene) raises the Stability value of control mix and the Percentage increases for Waste Plastics.

By, this it was stated that the Specific Gravity of Additive mixture is less than 1 which is less than that of Bitumen. Hence, it is stated that the penetration between Particles and inflate (Strengthen) the interlock of Aggregates, which increases the Stability and Decreases the flow value.

If we Increases the Additive Content beyond more than that it starts decreasing where the Stability Value Decreases i.e., parallelly interlocking between particles also decreases which is offered by bitumen binder and the remaining coated aggregate particle space will be occupied by the bitumen Content.

By testing the result it was concluded that Compared with Polypropylene additive mixture, waste Plastic Stability is more, Which indicates that Waste plastic maintains higher Resistances Compared with LDPE (Polypropylene).

Conclusion

As plastic is being a versatile material and a friend to common man in useful way become a problem to the ambient environment after its use. Today in India only, nearly 10 MILLION TONNES of plastic is used and hoped to reach 20 million tonnes by 2025. Being non-biodegradable. Waste plastic is the biggest issues in solid waste management. So, we have tried to replace bitumen in bituminous concrete.

As, Polypropylene is a thermoplastic polymer used in wide variety of applications it's help in replacing in bitumen with plastic.

As a Civil Engineers, we have came with an idea to utilize this waste plastic and polypropylene in bitumen to prepare bituminous concrete that will solve two problems

- Solid waste management issue
- Bituminous road problems

We have tried to replace bitumen in bituminous concrete that is usually used nowadays for Asphalting of Roads, by plastic and LDPE (Polypropylene). It will increases the melting point of the bitumen. In this process waste plastic and polypropylene which is evolved from (LDPE) is coated over the aggregates. By result it was concluded that compared with conventional bitumen mixture the stability has been increased by adding of waste plastic and LDPE (Polypropylene). But, in the flow test the conventional bitumen flow value is more compared with waste plastic and polypropylene. In Marshall Quotient also the values are increased with respect to the control Mixture of waste plastic and LDPE (PP).

By adding additive mixtures specific gravity range is in limits as like normal bitumen and it is found that it is slightly higher with waste plastics additive. As the density in the waste plastic and polypropylene is much less than that of aggregates it will penetrate easily into the aggregates, due to this there will be a proper interlocking between the particles which forms a perfect bonding over it.

As, we filled the properties with additive mixtures there will be less voids compared with conventional bitumen. This innovative technology not only strengthened the road construction but also increases the road life as well as help to improve the environment and also solves the solid waste management.

References

1. Sandhya K, Sanjay Kumar L, Rajkumar KN, Sandhya R, Sukuma S. Partial Replacement of Bitumen by using Waste Plastic in Bitumen Concrete Roads.
2. Payal Dubey, Nakul Gupta. Ph.D. Research Scholar From Civil

Engineering Dept, GLA University, Utilization of Low-Density Plastic Waste in Construction of Flexible Pavement with a Partial Replacement of Bitumen.

3. Aakash Bariya, Aakash Ved, Ganesh Chouhan, Lalit Yadav, Naveen Nayak, Rahul Surage *et al*. Scholar, Dept. of Civil Engineering, From Malwa Institute of Technology, Indore, M.P., India "Partial Replacement of Bitumen with Plastic Waste in Hot Mix, 2018.
4. Chandrasekaran M, Aadhil Bathusha SJ, Kanagarajan R, Karthikesh R, Kavin K. Assistant Professor, Department of Civil Engineering, Excel Engineering College, Komarapalayam, Tamil Nadu, India: Experimental Study on the Behavior of Flexible Pavements with Partial Replacement of Bitumen with Plastic Waste, 2017.
5. Gandhiraj J, Karthikeyan V, Rajasekar K, Rajesh Kumar N, Santhosh Kumar S, Sathya *et al*. Experimental Investigation on Road Pavement with Partial Replacement of Plastic Wastes as Bitumen, 2018.
6. Sathish U, Sandeep AV, Shyam Kumar K, Hari Gopal V, Hari Krishna K, Asha Jyothi J *et al*. B.Tech Civil Engineering Students, Sanketika Vidya Parishad Engineering College, Visakhapatnam. Partial Replacement of Bitumen with Waste Plastic in Flexible Pavements, 2020.
7. Surya B, Prakash R, Ranjithkumar S, Saravanan SM, Sivaraja M. UG Scholar, 4HoD/Civil, Principal, N.S.N. College of Engineering and Technology, Karur, Tamilnadu. An Experimental Investigation on Flexible Pavement with Partial Replacement of Bitumen by using Waste Plastic Biomedical Wastes and Bags, 2018.
8. Rahi DC, Chandhak R, Amit Vishwakarma. Department of Civil Engineering Jabalpur Engineering College. Utilization of Liquid Plastic Waste in Bitumen for the Road Construction.

Chapter - 2

High Performance Concrete using Silicafume and Superplasticizer

<u>Authors</u>

Shyamala Bhoomesh
Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

Somagari Pooja Sri Reddy
Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

D.V. Tanuja
Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

V. Naresh
Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

Chapter - 2

High Performance Concrete using Silicafume and Superplasticizer

Shyamala Bhoomesh, Somagari Pooja Sri Reddy, D.V. Tanuja and V. Naresh

Abstract

This work presents the study of effect of performance of HPC using mineral admixture i.e. silica fume with M-70 grade of IS cube specimen. We partially replaced cement by weight of binder with silica fume replacement with percentages of 5%, 7% and 9%. We used Conplast SP430-Sulphonated Naphthalene Polymers as a super plasticizer for better workability for top performance concrete. Dosage for super plasticizers is same 1% for all mix proportions. Also, we've investigated compressive strength, split lastingness and flexural strength for all different cases. The HPC mix, grade M70 concrete is supposed as per Indian standards “Guide for selecting proportions for top strength concrete with Pozzolana Portland cement and other cementitious materials”.

Keywords: High performance concrete, mineral admixtures, super plasticizers, etc.

1. Introduction

HPC could also be a construction material which is getting utilized in increasing volumes in recent years because of its future performance and better rheological, mechanical and durability properties than CC. Natural sources required for various constructions are getting depleted at a rapid rate, due to which there is always a rise in their price. This led the engineers and researchers in finding other substitutes for the production of construction materials keeping in mind of maintaining the quality, strength and durability. One of the most important constituents of concrete being coarse aggregate the fact being that it occupies 70-80% of the volume of concrete; thus, making a big impact on the characteristics and properties of concrete.

However, with the urbanization and rapid rise in the population especially in a country like India the demands for this particular construction material cannot be met easily. Hence, to overcome this problem is by using waste products such as waste ceramics.

In India the Ceramic Tile Industry approximate worth is Rs.21,000 Crore and was reported, the Indian Ceramic Tiles industry grew by around 11% in 2013-14 and expected to reach a size of Rs.301 billion by 2016. As in a present report of Global Ceramic Tiles Market of February 2016, the global ceramic tiles market will grow at a CAGR (Compound Annual Growth Rate) of 9.59% during the period of 2016-2020. Globally India is ranked 3 and accounted for over 6% of total global production. Even with a tremendous growth in the ceramic production there is an inappropriate consumption. Thus, resulting to a huge wastage which is reported to be around 15%-30% annually, generated from the total production. Ceramic products are manufactured at extremely high temperatures between 1000 °C-1250 °C which results in very hard, highly resistant to chemical, freezing and thermal shock. Considering the properties of ceramics their waste such as broken tiles should be included in concrete as a substitute to conventional construction material. This will help to solve problems like cost, scarcity as well as other environmental issues that may arise due to improper dumping of such waste.

HPC possess invariably high strength, reasonable workability and negligible permeability. Matchup to CC, preparation of HPC requires lower water binder (w/b) ratio and better cement content. The durability attributes of concrete are given importance, which makes High Strength Concrete (HSC) into HPC. HSC refers to concretes of grade above M60. High strength and better persistence properties become reality for CC by reducing porosity, in homogeneity, micro cracks in concrete and thus the transition zone. This is often how HPC is evolved.

The HPC allows the use of reduced sizes of structural member, higher building height in congested areas and early removal of formwork. The use of HPC in prestressed concrete construction makes greater span-depth ratio, early move of prestress and application of service loads. Low permeability qualities of HPC reduce the danger of corrosion of steel and charge of aggressive chemicals. This allows the use of HPC in marine/offshore structures, nuclear power plants, bridges and places of utmost and adverse climate. Eventually HPC reduces maintenance and repair cost.

2. Review of literature

R.M. Senthamarai *et al.* (2005) substituted conventional crushed stone aggregate with ceramic electrical insulator. Different water cement ratio of

0.35, 0.40, 0.45, 0.50, 0.55 and 0.60 were adopted. Compressive strength, split tensile strength, flexural strength and Modulus of elasticity were found out. It is found that the compressive, split tensile and flexure strength of ceramic coarse aggregate are lower by 3.8%, 18.2% and 6% respectively when compared to conventional concrete.

A. Mohd Mustafa *et al*. (2008) studied on various types of ceramic waste like flower pots, tiles and clay bricks. Different water cement ratios were adopted such as 0.4, 0.5 and 0.7 with concrete of characteristics strength of 20 MPa. Flower pots gave the best results for compressive strength of about 2.50% lesser than that of conventional concrete.

C. Medina *et al*. (2012) investigated on the reuse of waste as recycled coarse aggregate in partial substitution of 15%, 20% and 25% in the manufacture of structural concrete. Compressive strength is found out t 7, 28 and 90 days. There is an increase in strength with increase of percentage replacement, the best results shown is at 25% with increase of 21.12%, 11.04% and 6.70% at 7, 28 and 90 days respectively.

R.M. Senthamarai *et al*. (2011) studied the durability properties of ceramic industry waste as coarse aggregate in concrete. Water cement ratios from 0.35- 0.60 were used and properties such as volume of voids, water absorption, chloride penetration and sorption were studied. Water absorption ranges from 3.74-7.21% whereas that of conventional concrete from 3.1 – 6.52%. Concrete with Ceramic shows higher results in all tests.

T. Sekar (2011) studied on strength characteristics of concrete utilizing waste materials *viz*: ceramic tiles, ceramic insulator waste and broken glass pieces. Ceramic tiles gave the best results when compared to the other two type of waste. The concrete produced by ceramic tile aggregate produced similar strength in compression, split tensile and flexure as conventional concrete.

Y. Tabak *et al*. (2012) studied on the mechanical and physical properties of concrete produced form Floor Tiles Waste Aggregate (FTWA). Two samples were made, the first one substitution by Floor Tile Waste Dust (FTDA) and the other a combination of Floor Tile Waste Dust (FTDA) and Floor Tile Waste Aggregate (FTWA). Best result is shown b FTWA substitution. Increase in compression strength is 13.53%, 16.70% and 2.91% for 2, 7 and 28 days. Similarly there is an increase of 23.21%, 0.1% and 19.47% respectively for flexure strength.

There is a reduction of specific density and water absorption of 0.284Kg/m and 0.158% respectively when compared to conventional concrete. D. Tavakoli *et al*. (2013) investigated on the possibility of using ceramic tile in concrete. Coarse aggregate is replaced in the range of 0-40%. There is an increase in compressive strength by 5.13% whereas there is a decrease in slump, water absorption and unit weight by 10%, 0.1% and 2.29% respectively with 10% substitution.

Maya *et al*. (2014) studied the mechanical properties of roof tiles as coarse aggregate with different ratios of 0.40, 0.45 and 0.50, subjected to elevated temperature. There is a decrease in compressive strength and Split Tensile with increase in water cement ratio and temperature.

Umapathy *et al*. (2014) studied on Rice Husk Ash (RHA) as cement at 10%, 15% and 20% and waste tiles as coarse aggregate at 20%, 30% and 50%. Compression strength is found out and the best results is with 20% tiles and 10%RHA of 80.60% to that of conventional concrete.

Amir Javed *et al*. (2015) analysed the compressive and flexural strength of concrete with stone dust as natural sand at 20%, 40%, 60%, 80% and 100% along with ceramic waste as stone aggregate at 20% replacement. It is found that at 40% stone dust and 20% ceramic waste compressive strength reaches upto 77.32% of that of conventional concrete whereas there is an increased in flexure strength by 25.62%.

J. Swathi *et al*. (2015) partially replaced fine aggregate with copper slag as 20%, 40% and 60% and coarse aggregate with waste ceramic tiles as 10%, 20% and 30%. M40 grade of concrete was used. Compressive strength increased by 7.59N/mm at a combination of 40% copper slag with 10% waste ceramic tiles and also Flexure increased by 4.07%.

Suresh Kumar A. (2018): He investigated the likelihood of developing high performance concrete (HPC) by using micro silica with water cement ratio as 0.35. He designed for M70 Grade concrete. When cement is replaced with 10%by silica fume the 28days compressive strength is observed as 61.33mpa. And whereas for split tensile it is15.59% higher & for flexural if it's 22.80% higher.

R.M. Karthikeyan (2017): within the present study the combination Design for M60 grade concrete and is completed consistent with ACI211.4R. The varied mix proportions of the concrete are done. By replacing cement with 40% & 50% of ash and 10% of Silica fume & metakaolin high strength concrete is obtained. Whereas 50% replacement of ash and 10% of silica fume with cement gave better compressive strength that's 64.3Mpa.

Dr. Moslih Amersalih (2018): He investigated to gauge the compressive strengths & durability properties of HPC which contains micro silica and ash as partial replacement of OPC. The cubes were casted for M70 grade concrete with the 30% of 21 ash, 7% of micro silica and 25% of ash and micro silica, it's a binary mixture which has shown the great performance in concrete. But it's been reported that the utilization of ash & micro silica because the practical replacement the water absorption has increased. Using of 30kg/m of micro silica and 126kg/m ash has achieved the high compressive strength result, the micro silica with 7%replacement features a tremendous effect to resist the chloride penetration. Use of ash with 30% to twenty which is mixed with 5% of micro silica has shown the low chloride ion permeability.

Jafar Shafaghat (2019): during this paper the micro silica is employed by replacing in cement. He used the RPRAC i.e., reactive powder reactive aggregate concrete and hydraulic cement clinker as sand replacement. The combination is meant for M100 grade. Where the compressive strengths has increased to 169.4% & 122.9% for 28 & 60 days where he concluded that the replacement level is optimized to 64%by weight of powder.

A Parvathy Karthika (2018): during this paper she analyzed the performance of concrete with various combinations during which the cement is partially replaced with ash i.e., 30% and Alccofine of grade 1203 with micro fine silica as 0, 4, 8, 12% respectively. He casted cubes for M60 grade used M Sand as fine aggregate. The result shown that the water absorption and permeability decreases with the increasing Alccofine content. The concrete mix proportion which consists 30% ash and 12% Alccofine is best among all other combinations.

3. Significance and objectives

According to nevillie "HPC could also be a concrete to satisfy determined purpose and no special mystery about it, no unusual ingredients or special equipments possesses to use. Butto understand the behavior of concrete and may, to provide a concrete mix within closely controlled tolerances". The aim of this investigation are to develop a clarify mix design procedure, especially for HPC by varying the share replacement of cement by silica fume (0-15%) at a unbroken dosage of super plastisizer, recommended by IS 10262:2019 code method of mix design procedure and available literatures on HPC. Investigations were administered on the above procedure to provide HPC in mixe for M70 grade using 12.5 mm and 20 mm maximum size of aggregates to determine workability and thus the mechanical properties of the designed mix and to hunt out an optimum cement replacement by SF. Hence within this investigation more emphasis is given to study the HPC using silica fume and super plasticizer soon reach better concrete composite and also to encourage the increased use of silica fume to require care of ecology.

4. Experimental program

Experimental investigations are administered on the HPC specimens to work out the workability and strength related properties like compressive strength, split tensile strength, flexural strength of the concrete.

a) Materials used

Silica fume as mineral admixture in dry congealed form obtained from ELKEM INDIA (P) LTD, Mumbai conforming to ASTMC-1240. Super plasticizer (chemical admixture) supported sulphonated naphthalene formaldehyde condensate- CONPLAST SP 430 compatible to BIS: 9103-1999 and ASTM C-494.

b) Mix Design for HPC

Since there aren't any specific methods for mix design found suitable for HPC, a clarify mix design procedure, is formulated by IS 10262:2019 method for concrete mix design and thus the available literatures on HPC using SF.

1) Calculation of binder contents

The binder or cementitious list per m2 of concrete is calculated from the w/b ratio and thus the number of water content per m3 of concrete. Assuming the share replacement of cement by SF (0-15%), the SF content is obtained from the whole binder contents. The remaining binder content consists of cement. The cement content so calculated is verified against the minimum cement Experimental Investigation on High Performance Concrete Using Silica Fume and Super plasticizer

2) Moisture adjustments

The actual amounts of CA, FA and water content are calculated after allowing necessary corrections for water absorption and free (surface) dampness content of aggregates. The volume of water included within the liquid plasticizer is calculated and subtracted from the starting mixing water

3) Unit mass of concrete

The mass of concrete per unit content is calculated by adding the masses of the concrete ingredients.

4) Selection of water- binder (w/b) ratio

The water binder ratio for the design average compressive strength is chosen from figure IS10262 – 2019 w/C ratio

5) Trial mix proportion

Because of many assumptions underlying the forgoing conceptual calculations, the trial mix proportions must be checked, if necessary the mixture proportion should be modified to meet the required workability and strength criteria, by adjusting the half replacement of cement by SF, % dosage of super plasticizer solid satisfied of binder, air content and unit weight by means of laboratory trial mixes to optimize the mix proportion. Fresh concrete should be tested for workability, unit weight and air content. Specimens of hardened concrete should be tested at the determined age.

6) Mixer proportions and casting of specimens

Mix proportions are arrived for M70 grade of concrete supported the above formulated mix design procedure by replacing 0, 5%, 7%, and 9% of the mass of cement by SF and thus the fabric requirements perm^3 of concrete. The ingredients for the numerous mixes are weighed and mixing was carried out employing a drum type mixer and casting were exhausted steel moulds for concrete cubes 150mm size, cylinders 150mm x 300mm and beams 100mm x 100mm x 500mm. Curing was done under water for various wanted periods.

5. Tests on fresh and hardened concrete

Workability tests like slump test, compaction factor test test were administered for fresh concrete as per IS specifications, keeping the dosage of super plasticizer as constant at 1% by weight of binder. For strongest concrete cube compression strength test on150mm size cubes at the age of 1 day, 7 days, 14 days, 28 days curing were administered using 3000kN capacity compression testing machine as per IS 516-1956 Also compression strength evaluation and split tensile strength on 150mmx300mm cylinders and flexure evaluation on 100mmx100mx500mm beams were administered on 28 days cured specimens as per IS specifications. The stress- strain diagram for HPC is obtained using compresso-meter fitted to cylinders during cylinder compressive strength test.

6. Discussions and conclusions

Based on the investigations administered on HPC mixes the following conclusions are drawn.

1) High performance concrete (HPC) was designed by using recommendations of IS10262:2019 method of mix design. High performance concrete (HPC) are often developed with 5%, 7%, 9% replacement of cement with Silica fume to achieve desired high strength of M70 grade.

2) Silica fume chosen for the study has high pozzolanic index and strength activity index. These indices confirm that silica fume chosen has high reactivity. The fresh high

3) Performance concrete mixture with the utilization of SP and therefore the incorporation of silica fume provided a far better workability than the OPC one.

4) The HPC designed with less cement and water contents obtained higher long-term compressive strength and lower water absorption rate than the OPC or conventional concrete.

5) This study is primarily focused on the properties of materials used, mix proportion of high performance Concrete, making of concrete specimen, curing and testing of harden concrete. On performing the varied tests the physical properties of the specimens are studied and therefore the following conclusions are arrived.

References

1. Suresh Kumar A, Aaravindhraj M, Samuel Gnaniah. Behaviour of high performance concrete with micro silica and flyash. International Journal of research project Engineering & Technology (IJSRET), ISSN 2278 – 0882, 2018, 7(5).
2. Karthikeyan RM, Ramkumar KM, Jayalin D. Experimental Study on High Performance Concrete and High Volume Flyash Concrete using Polypropylene Fibre, International Journal of ChemTech Research CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online): 2455-9555. 2017;10(8):276-283.
3. Moslih Amer Salih. Strength and sturdiness of high performance concrete containing ash and micro silica, International Journal of engineering and Technology (IJCIET). 2018;9(9):104-114. Article ID: IJCIET_09_09_013 Available online at http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=9&IType=9
4. Jafar Shafaghat, Ali Allahverdi. Agument Concrete Properties by Using Silica Fume as Reactive Powder and Portland Cement-Clinker as Reactive Aggregate.

5. Parvathy Karthika, Gayathri V. Experimental Studies on peresistance Aspects of High Strength Concrete using Flyash and Alccofine, International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, 2018, 7(4S).
6. Senthamarai RM, Devadas Manoharan P. Concrete with Ceramic Waste Aggregate, Elsevier, Cement and Concrete Composites. 2005;27:910-913.
7. Mohd Mustafa Al Bakri A, Norazian MN, Kamarudin H, Che Mohd Ruzaidi G. The Potential of Recycled Ceramic Waste as Coarse Aggregates For Concrete, Malaysian Universities Conferences on Engineering and Technology, 2008, 1-3.
8. Medina C, Sanchez de Rojas MI, Frias M. Reuse of Sanitary Ceramic Wastes as a Coarse Aggregate in Eco-Efficient Concrete, Elsevier, Cement and Concrete Composites. 2012;34:48-54.
9. Senthamarai RM, Devadas Manoharan P, Gobinath D. Concrete Made From Ceramic Industry Waste: Durability Properties, Elsevier, Construction and Building Materials. 2011;25:2413-2419.
10. Sekar T. Study on Strength Characteristics on Utilisation of Waste Materials As Coarse Aggregate in Concrete, International Journal of Engineering Science and Technology. 2011;3(7):5436-5440.
11. Tabak Y, Kara M, Gunay E, Yildirimand ST, Yilmaz S. Ceramic Tile Waste As a Waste Management Solution For Concrete, CRETE, 2012.
12. Tavakoli D, Heidari A, Karimian M. Properties of Concrete Produced with Waste Ceramic Tile Aggregate, Asian Journal Of Civil Engineering. 2013;14(3):369-382.
13. Shler Saeed Qadir. Strength and Behavior of Self Compacting Concrete with Crushed Ceramic Tiles as Partial Replacement for Coarse Aggregate and Subjected To Elevated Temperature, International Journal of Engineering Technology, Management and Applied Sciences, 2015, 3(4). ISSN.2349-4476.
14. Giridhar V, Sudarsana Rao H, Ghorpade G. Development of Regression Models for Stregth of Ceramic Waste Aggregate Concrete, International Journal of Emerging Trends in Engineering and Development, 2015, 1(5). ISSN. 2249-6149.

Chapter - 3

A Study on Waste Plastics Effectively using in Concrete Blocks

Authors

C.M. Vivek Vardhan
Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

A. Naga Sai Baba
Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

G. Venkatesh
Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

J.S.S.K. Vasa
Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

Chapter - 3

A Study on Waste Plastics Effectively using in Concrete Blocks

C.M. Vivek Vardhan, A. Naga Sai Baba, G. Venkatesh and J.S.S.K. Vasa

Abstract

We have made an experiment by partially replacing fine aggregate and coarse aggregate with plastic powder and ceramic waste respectively. The strength properties of M20 grade concrete are studied with different plastic powder and ceramic waste percentage proportions. The proportions are 15% of plastic powder, 15% of ceramic waste and 20% of plastic powder, 20% of ceramic waste are replaced with fine and coarse aggregate by volume. We studied strength properties of these mixes. There is increase in compressive strength when the ratio of plastic and ceramic to fine and coarse aggregate respectively was minimum. The workability of the concrete mix has been increased. Based on the test results we can suggest that the plastic and ceramic can be used as alternative material within the small replacement proportions.

Keywords: Concrete blocks, plastics materials, gradings.

1. Introduction

Concrete consists of cement, coarse and fine aggregates mixed with water. The cement and water form a paste or gel which coats the fine and coarse aggregate. When the cement has chemically reacted with the water, it hardens and binds the whole mix together. The worldwide production of concrete is 10 times that of steel by tonnage. These wastes (plastic) are almost non-degradable in the natural environment even after a long period of exposure. So, plastic waste is now a serious environmental threat to the modern way of living. It is not feasible to use waste plastic for land filling, which require huge land space area and as well land loses its fertility. It also causes serious problems such as clogging in drainage system, wastage of resources and environmental pollution. In this consequence, big attention is being focused worldwide on the environment and safeguarding the natural resources through recycling of waste plastic materials in the recent years.

Since the expansive request has been set on building fabric industry particularly within the final decade owing to the expanding populace which causes a inveterate deficiency of building materials, the gracious engineers have been challenged to change over the mechanical squanders to valuable building and development materials. Collecting of unmanaged squanders particularly in creating nations has brought about in an expanding natural concern. Reusing of such squanders as building materials shows up to be reasonable arrangement not as it were to such contamination issue but too to the issue of financial plan of buildings. The increment within the ubiquity of utilizing naturally inviting, low-cost and lightweight development materials in building industry has brought about the have to be examine how this could be accomplished by profiting to the environment as well as keeping up the fabric prerequisites confirmed within the measures. Numerous past inquires about attempted gotten profitable comes about to utilize the mechanical squanders in different shapes of concrete generation. For occurrence, the utilize of squander elastic, glass powder and paper squander slime in concrete blend has gotten conscribe consideration over the past a long time. A few inquires about carried out within the past utilized wood cinder squanders as a substitution for cement in concrete blends. In spite of the fact that these inquires about are giving empowering comes about, the concrete blends having both wood sawdust squanders (WSW) and limestone powder squanders (LPW) combination up to this point has not been examined. These squanders utilized in this inquire about are broadly accessible in huge sum from the woodland and limestone businesses. This paper presents a few physical and mechanical properties of the concrete blends having tall level of WSW and LPW as a substitution for aggregate. Most of the squanders utilized in this investigate are as of now arranged in clean landfills or open-dumped into uncontrolled squander pits and open ranges.

Objectives: The specific objectives are to:

- To analyze the properties of plastic powder as fine aggregate and ceramic waste as coarse aggregate.
- To test the properties of concrete using plastic powder as fine aggregate and ceramic waste as coarse aggregate.
- To prepare different mixes of concrete with replacement fine aggregate with plastic powder and ceramic waste as coarse aggregate.

2. Literature review

Ramadevi [2012] conducted an experimental investigation on the properties of concrete with plastic PET (bottle) fibers as fine aggregate.

Concrete with 2%, 4% and 6% PET bottle fibers replacement for fine aggregate were produced and compared against control mix with no replacement. The compressive and the tensile strength of the replaced concrete were higher when compared with the normal concrete.

Silva [2013] conducted experiment on the effect of curing conditions on the durability of concrete mixes containing plastic waste aggregates. Concrete mixes were prepared by replacing 0%, 7.5% and 15% of natural aggregates with plastic - polyethylene terephthalate (PET). Tests are done for shrinkage, water absorption by immersion, water absorption by capillarity action, carbonation and chloride penetration. The sensitivity analyses showed that the properties of concrete mixes containing plastic aggregates generally deteriorate less than those of conventional concrete, when subjected to progressively drier curing regimes.

Guendouz [2016] conducted experiments on properties of the concrete by replacing fine Aggregate with plastic waste at different proportions 10%, 20%, 30%& 40% respectively. The results states that the replacement of sand contributes to reduce the bulk density, decreases the air content causing an increase a compressive and flexural strength. In addition the reinforcement of the cementing matrix with plastic fibers induced a clear improvement of the tensile strength. The reusing waste plastic in sand concrete gives positive approach to reduce the cost of materials and solve some environmental problems.

3. Materials and methods

a) Materials

1) Cement (OPC53 grade conforming to IS 8112)
2) Coarse aggregates and fine aggregates
3) Plastic powder
4) Ceramic waste

Ordinary portland cement [OPC]: Ordinary Portland cement is the most common type of cement used in making concrete around the world for infrastructure development. It is a mixture of fine lime powder and clay minerals produced in a kiln to form ac linker which will be grinded to fine particles and finally added gypsum ofabout2- 3%. OPC will be grey in colour

Coarse aggregate: The coarse aggregate is generally quarried rock from ground deposits. The size of coarse aggregate used in concrete generally is in the range of 4.75mm to 80 mm. The coarse aggregate is the reason beyond the strength of concrete. The coarse aggregate is different shapes generally like round, flaky, angular etc. The nominal size of aggregate used in this experiment is 20mm and angular shaped.

Fig 1: Ceramic waste

Fig 2: Plastic powder

Fine aggregate: Fine aggregate (sand) fills voids between aggregates. It forms the bulk and makes mortar or concrete economical. It provides resistance against shrinking and cracking. It is naturally available. The aggregates passing through 4.75mm sieve and retained on 0.15 mm sieve are called fine aggregates. Different size of sand is necessary for different works. For sand some terms like fine sand, medium sand, and coarse sand are used. It is difficult to distinguish one type of sand from others.

Ceramic waste: After the demolition of the building the waste left out. The used in any building are made up of ceramic material. These tiles can be used as waste ceramic material replacement of coarse aggregate. The ceramic waste tiles have been collected from construction waste is taken then it is broken down into small pieces by hammering. These small ceramic waste pieces can be used for the replacement of coarse aggregate.

Plastic powder: There is huge amount of plastic water bottles are disposed in different areas in our surroundings. The waste plastic bottles are converted into plastic powder. Initially the plastic water bottles will be cutting into small pieces then it is converted into powder form. This plastic powder is used as material for replacement of fine aggregate.

b) M20 Grade concrete mix proportioning

Cement = 345.45 kg/m^3 Water = 190 kg/ m^3 sand = 607.36 kg/m^3

Coarse aggregate = 792.82 kg/m^3 Plastic powder = 64.12 kg/m^3 Ceramic waste = 134.08 kg/m^3

Chemical admixture = 7.2 kg/m^3 Water cement ratio= 0.55

Final mix ratio: Cement: fine aggregate: coarse aggregate: water = 1:1.943:2.683:0.55

4. Tests on fresh and hardened concrete

Workability tests like slump test, compaction factor test were administered for fresh concrete as per IS specifications. Compression strength test and split tensile strength on were administered at the age of 14 days, 28 days as per IS specifications.

Slump cone test: Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory. If the concrete slumps evenly it is called true slump. If one half of the cone slides down, it is called shear slump. In case of a shear slump, the slump value is measured as the difference in height between the height of the mould and the average value of the subsidence.

Fig 3: Slump cone test

Compaction factor test: The compaction factor test is used for concrete which have low workability for which slump test is not suitable. The compacting factor test is performed to ascertain the workability of the concrete. The compaction factor is defined as the ratio of the weight of partially compacted concrete to the weight of fully compacted concrete.

Fig 4: Compaction Factor Test

Fig 5: Compressive testing specimen size: cubes (15cm X 15cm 15cm)

Compressive strength test: The compressive strength of the concrete cube test provides an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not.

Pouring concrete in moulds: Clean the moulds properly and finish it with oil so that concrete will not stick into the mould and make latter cleaning difficult. Put concrete in the moulds layer by layer. Each layer is around 5 cm thick. Each layer is compacted with a tamping rod [35 strokes]. Level the top surface with a trowel.

Curing: Test specimens are kept in the moulds and stored in moist air for 24 hours and then, the specimens are removed from the moulds and submerged in fresh water for the specified curing period.

Split tensile test: The tensile strength of concrete is one of the basic and important properties which greatly affect the extent and size of cracking in structures. Moreover, the concrete is very weak in tension due to its brittle nature. Hence. it is not expected to resist the direct tension. So, concrete develops cracks when tensile forces exceed its tensile strength.

Therefore, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. Furthermore, splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The procedure based on the ASTM C496 (Standard Test Method of Cylindrical Concrete Specimen) which similar to other codes like IS 5816 1999.

Fig 6: Split tensile testing machine

5. Discussions and conclusions

The present study aimed the use of two types of wastes (plastic powder and ceramic waste) as partial replacement of fine and coarse aggregate in concrete;

a) Plastics (plastic powder and ceramic waste) can be used to replace some of the aggregate in a concrete mixture as it contributes to reducing the unit weight of the concrete, due to low density of plastics as compared to the density of fine aggregates.

b) It was observed in the result that the slump decreases with increase in the percentage of plastic (plastic powder and ceramic waste), due to the fact that some particles are angular and others have non-uniform shapes resulting in less fluidity.

c) The recycled plastic (plastic powder and ceramic waste) aggregates can be used up to 15% replacement of fine aggregates in the concrete mixture.

d) The use of waste plastic (plastic powder and ceramic waste) in cement based composite can significantly reduced cost of construction through full or partial replacement of aggregates.

e) The used of waste plastics (plastic powder and ceramic waste) in constructions will grossly reduced rate of solid waste accumulation in the environment and income will be generated from its utilization.

References

1. Harini B, Ramana KV. Use of recycled plastic waste as partial replacement for fine aggregate in concrete. International Journal of Innovative Research in Science, Engineering and Technology. 2015;4(9):8596-8603.
2. IS: 383-1970, Specification for coarse and fine aggregate, Bureau of Indian Standards, New Delhi, 1970.
3. IS 456:2000 Indian standard- Plain & Reinforced Concrete, New Delhi, 2000.
4. IS: 2386-1963, Methods of test for aggregates of concrete, part I, III & IV, Bureau of Indian Standards, New Delhi, 1963.
5. IS: 10262-2009, Guidelines for concrete mix design proportioning, Bureau of Indian Standards, New Delhi, 2009.
6. Jassim AK. Recycling of polyethylene waste to produceplastic cement. Procedia manufacturing. 2017;8:635-642.
7. Raghatate Atul M. Use of plastic in a concrete to improve its properties. International journal of advanced engineering research and studies. 2012;1(3):109-111.
8. Rahman MM, Mahi MA, Chowdhury TU. Utilization of waste PET bottles as aggregate in masonry mortar. International Journal of Engineering Research & Technology (IJERT). 2013;2(11):1030-1035.
9. Rahmani E, Dehestani M, Beygi MHA, Allahyari H, Nikbin IM. On the mechanical properties of concrete containingwaste PET particles. *C*onstruction and Building Materials. 2013;47:1302-1308.

Chapter - 4

Brick Material by Replacing Cement and Sand with Limestone Dust and Wood Saw Dust

Authors

K. Haeshada
Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

M. Uday Bhaskar
Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

S. Manasa
Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

G. Naveen Kumar
Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

M. Venkatesh Reddy
Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India

Chapter - 4

Brick Material by Replacing Cement and Sand with Limestone Dust and Wood Saw Dust

K. Haeshada, M. Uday Bhaskar, S. Manasa, G. Naveen Kumar and M. Venkatesh Reddy

Abstract

The majority of abandoned limestone powder wastes (LPW) and wood sawdust wastes (WSW) is accumulated from the countries all over the world and causes certain serious environmental problems and health hazards. This project a parametric experimental study which investigates the potential use of WSW–LPW combination for producing a low-cost and lightweight composite as a building material. Some of the physical and mechanical properties of concrete mixes having high level of WSW and LPW. The obtained compressive strength and water absorption values the relevant international standards. The results show that the effect of high-level replacement of WSW with LPW does not exhibit a sudden brittle fracture even beyond the failure loads, indicates high energy absorption capacity, reduces the unit weight dramatically and introduces smother surface compared to the current concrete bricks in the market. It shows a potential to be used for walls, wooden board substitute, economically alternative to the concrete blocks, ceiling panels, sound barrier panels, etc.

Keywords: LPW, WSW, materials

1. Introduction

Since the expansive request has been set on building fabric industry particularly within the final decade owing to the expanding populace which causes a inveterate deficiency of building materials, the gracious engineers have been challenged to change over the mechanical squanders to valuable building and development materials. Collecting of unmanaged squanders particularly in creating nations has brought about in an expanding natural concern. Reusing of such squanders as building materials shows up to be reasonable arrangement not as it were to such contamination issue but too to the issue of financial plan of buildings. The increment within the ubiquity of utilizing naturally inviting, low-cost and lightweight development materials in building industry has brought about the have to be examine how this could be accomplished by profiting to the environment as well as keeping up the fabric prerequisites confirmed within the measures.

Numerous past inquires about attempted gotten profitable comes about to utilize the mechanical squanders in different shapes of concrete generation. For occurrence, the utilize of squander elastic, glass powder and paper squander slime in concrete blend has gotten conscribe consideration over the past a long time. A few inquires about carried out within the past utilized wood cinder squanders as a substitution for cement in concrete blends.

In spite of the fact that these inquires about are giving empowering comes about, the concrete blends having both wood sawdust squanders (WSW) and limestone powder squanders (LPW) combination up to this point has not been examined. These squanders utilized in this inquire about are broadly accessible in huge sum from the woodland and limestone businesses. This paper presents a few physical and mechanical properties of the concrete blends having tall level of WSW and LPW as a substitution for aggregate. Most of the squanders utilized in this investigate are as of now arranged in clean landfills or open-dumped into uncontrolled squander pits and open ranges.

2. Literature review

- **Utilization of limestone dust in brick making**

A.A. Mageeda and Gamal S. Abdel Haffez Assiut Univ., Faculty of Eng. Dept. of Mining & Metall., Assiut, Egypt on Secondment to king Abdul Aziz Univ., Jeddah, Saudi Arabia

The positive utilize of these squanders changes over them into valuable items that can ease the transfer and natural problems. The gotten comes about in this consider lead to the taking after conclusions: * The comes about appear that combination of limestone clean and cement can be utilized within the generation of stone work building bricks with satisfactory mechanical properties which coordinate the Egyptian Standard details of non- stack bearing walls. * The included cement within the blend influences emphatically the considered properties of the created bricks. * Sensible quality brick can be produced with expansion of around 13% cement, within the blend, which accomplished strength of 33 kg f /cm2 and 45 kg f /cm2 individually within the two-tested arrangement. These values fulfill the necessities for buildings of non – stack bearing dividers (25 to 45 kg f /cm2). * The created bricks have the taking after properties: 20-21% water retention, bulk thickness of 1.65-1.68 g/cm3 slake toughness of over 95% and compressive quality of 33-45 kg

- **A ponder of brick mortar utilizing sawdust as fractional substitution for sand**

Jonathan Sasah and Charles K. Kankam, Office of Gracious Designing, Kaaf College College, Bujumbura, Ghana.

The following Conclusions are observed:

Mortar prepared with sawdust as partial fine aggregates was investigated. Standard mortar of mix ratio of 1:3 andin inadequate workability. In view of that a modified mortar of better workability with constant slump of 74.3 mm was also prepared. The compressive strength and flexural tensile strength of the mortar and masonry compressive strength of wallets were assessed from test specimens. The results showed that the sawdust possessed the characteristics of a well-graded aggregate. The dry density, compressive strength and flexural tensile strength were observed to decrease with increasing sawdust content. A more porous mortar was produced with increased sawdust content. However the modified mortar was slightly impervious compared with the standard mortar. Therefore in terms of durability the modified mortar could be presumed to be more durable. At higher percentages of sawdust the crushing of the cubes was not sudden compared to the control for both mortar types. Failure of masonry wallets for the modified mortar was characterized by cracking along the masonry units whilst that of the standard mortar was observed to fail along the brick-mortar joint. This can be observed. The better bonding in the case of the modified mortar could be attributed to the improved workability which led to better adhesion between the bricks and the mortar. On a micro-scale the better adhesion could be also be due to sawdust fibres penetrating into the block surfaces.

The densities of both mortars decreased considerably with each percentage replacement. Low density mortar could be achieved by the partial replacement of the fines with sawdust. A thorough examination of the above results and discussions shows that there is a possibility of replacing fine aggregates with sawdust in masonry mortar preparation. With 8 and 13% percentages of replacement, the standard and modified mortars respectively produced mortars with properties which compare adequately well with theoretical values of BS 5628:1992 Code.

- **Limestone dust and wood sawdust as brick material**

Paki Turgut, Halil Murat Algin Department of Civil Engineering, Harran University, Osmanbey Campus, Sanliurfa, Turkey

The majority of abandoned limestone powder wastes (LPW) and wood sawdust wastes (WSW) is accumulated from the countries all over the world and causes certain serious environmental problems and health hazards. This paper presents a parametric experimental study which investigates the potential use of WSW–LPW combination for producing a low-cost and lightweight composite as a building material. Some of the physical and mechanical properties of concrete mixes having high level of WSW and LPW are investigated. The obtained compressive strength, flexural strength, unit weight, ultrasonic pulse velocity (UPV) and water absorption values satisfy the relevant international standards. The results show that the effect of high-level replacement of WSW with LPW does not exhibit a sudden brittle fracture even beyond the failure loads, indicates high energy absorption capacity, reduces the unit weight dramatically and introduces smother surface compared to the current concrete bricks in the market. It shows a potential to be used for walls, wooden board substitute, economically alternative to the concrete blocks, ceiling panels, sound barrier panels, etc.

3. Experimental work

Materials used

- Cement
- Gypsum
- Fine Aggregates- Sand
- Fly ash
- Limestone dust
- Wood saw dust
- Water

Cement

Portland cement is the product obtained by pulverization of clinker, which essentially consists of hydraulic calcium silicates, with a certain proportion of natural calcium sulfate that contains additions of substances to modify its properties or facilitate its use. The physical properties of the cement are listed in Table.

S. No.	Properties	Results	IS: 12269-1987
1.	Specific gravity	3.15	-
2.	Normal consistency	32%	-
3.	Initial setting time	60 Min	Minimum of 30min
4.	Final setting time	350 Min	Maximum of 600min
5.	Compressive strength A. 3 days strength B. 7 days strength C. 28days strength		Minimum of 27 Mpa Minimum of 40 Mpa Minimum of 53 Mpa

Gypsum

Gypsum may be a delicate sulfate mineral composed of calcium sulfate dihydrate, with the chemical equation $CaSO_4$, $2H_2O$. It is broadly mined and is used as a fertilizer, and as the most constituent in numerous shapes of mortar, chalkboard chalk and wallboard. Gypsum employments incorporate: fabricate of wallboard, cement, mortar of Paris, soil conditioning, a solidifying retarder in Portland cement. Assortments of gypsum known as "glossy silk fight" and "alabaster" are utilized for a assortment of fancy purposes; in any case, their low hardness limits their toughness. Vent Gas Desulfurization (FGD) gypsum is additionally known as scrubber gypsum. FGD gypsum is the by-product of an discuss contamination control framework that evacuates Sulfur from the vent gas in calcium-based scouring frameworks. It is delivered by utilizing constrained oxidation within the scrubber and is composed generally of calcium sulfate. FGD gypsum is most commonly utilized for agrarian purposes and for wallboard generation.

The properties of gypsum are listed in Table – 3.4

Properties	Gypsum
Chemical classification Colour Streak	Sulphate Clear, Colourless, White, Grey, Yellow, Red, Brown White
Luster Diaphaneity Cleavage Mohs hardness Specific gravity Diagnostic properties Chemical composition Crystal system	Vitreous, Silky, Sugary Transparent to translucent Perfect 2 2.3 Cleavage, Specific gravity, Low hardness Hydrous calcium sulphate Monoclinic

Fine aggregate

The standard sand used in this investigation was obtained from penna River in Nellore. The standard sand shall be of quartz, light grey or whitish variety and shall be free from silt. The sand grains shall be angular; the shape of the grains approximating to the spherical form elongated and flattened grains being present only in very small or negligible quantities. The standard sand shall (100 percent) pass through 2-mm IS sieve and shall be (100 percent) retained on 90-micron IS Sieve and the sieves shall conform to IS 460 (Part: 1): 1985.

Physical properties of sand are listed in Table – 3.2

Colour	Light yellow
Specific gravity	2.65
Shape of grains	Rounded

Flyash

Fly ash can be referred as either pozzolanic or cementitious. A cementitious material is one that hardens when mixed with water. A pozzolanic material also hardens when mixed with water but only after activation with an alkaline substance such as lime. Due to cementitious and pozzolanic properties of fly ashes they are used for replacement of cement in concrete and many other building applications.

The physical properties are

Physical properties	**Fly ash**
pH	6.0 – 10.0
Specific gravity	1.45 – 2.25
Bulk density(g/cc)	0.85 - 1.2
Grain size distribution	Silt to silty loam
Porosity (%)	45 – 55
Water holding capacity (%)	25 – 40
Electrical conductivity (ds/m)	0.15 – 1.10

Limestone dust

Crushed Limestone Dust. We supply Crushed Limestone Dust, available from our Ardsley and Bufford quarries. These materials are suitable for cable ducting, reconstituted stone manufacture, agricultural lime for soil improvement. The main application is for agricultural purposes, for neutralizing acidic soils.

Wood saw dust

Sawdust is the main component of particleboard. Wood dust is a form of particulate matter, or particulates. Research on wood dust health hazards comes within the field of occupational health science, and study of wood dust control comes within the field of indoor air quality engineering

Water

Portable water was used in the experimental work for both preparing and curing. The pH value of water taken is not less than 6.

Mixing design

Calculation per one brick

An example of calculating the required quantities of different materials for a considered proportion is given below:

- Dimension of the cube= 23*15*14cm
- Volume of the cube= 4830 cm3 =4830*(10-2)3
- Let, density of Brick=22 KN/m3= 22×1000⁄9.81= 2242.61kg/m3

We know that, mass=density × volume

=2242.61×4830×10-3

=10831.80Kg

∴The total weight of the sample=10831.80Kg

Ratio of binder to aggregate as 1:4

The water cement ratio as 0.62

∴The weight of binder= 10831.80/3=3610.6Kg

Weight of aggregate (Quarry dust) = 3610.6×4=14442.4.8kg

Weight of water= 0.62×3610.6= 2238.57Kg

Therefore, to prepare a brick of 23*15*14 cm dimension the amount of binder, quarry dust and fluid to be taken are 3610. 6kg, 14442.4kg and 2238.57kg respectively.

After all the ingredients were ready, the mixing was done. In this project, mixing was done manually. The mixing process of cement blocks are different. The exact mix proportion was not known. So, trial proportions were used in this project

Manufacturing process

The process of manufacture of cement concrete hollow blocks involves the following 6 stages;

1) Proportioning
2) Mixing
3) Moulding
4) Curing
5) Drying

Proportioning

- The determination of suitable amounts of raw materials needed to produce mortar of desired quality under given conditions of mixing, placing and curing is known as proportioning.
- As per Indian Standard specifications,
- Mix ratio of mortar 1:4.
- Water cement ratio of 0.62 by weight basis can be used for cement bricks.
- Moulds size 23*15*14 cm

Mixing

- Mixing is simply defined as the "complete blending of the materials which are required for the production of a homogeneously".
- Once the appropriate mixing has been chosen, it is necessary to determine the mixing time.

Moulding

- The purpose of moulding is to fill all air pockets with mortar as a whole without movement of free water through the mortar. Excessive moulding would result in formation of water pockets or layers with higher water content and poor quality of the product.

Curing

- Bricks removed from the mould are protected until they are sufficiently hardened to permit handling without damage.
- This may take about 24 hours in a shelter away from sun and winds.
- The bricks thus hardened are cured in a curing yard to permit complete moisturization for atleast 21 days. When the bricks are cured by immersing them in a water tank.

- The greatest strength benefits occur during the first three days and valuable effects are secured up to 10 or 14 days. The longer the curing time permitted the better the product.

Drying

- Bricks shrinks slightly with loss of moisture. It is therefore essential that after curing is over, the bricks should be allowed to dry out gradually in shade so that the initial drying shrinkage of the bricks is completed before they are used in the construction work.
- Generally, a period of 7 to 15 days of drying will bring the bricks to the desired degree of dryness to complete their initial shrinkage. After this the bricks are ready for use in construction work

4. Tests on bricks & results

Following tests are conducted on bricks to determine its suitability for construction work.

1) Water absorption test
2) Crushing strength test
3) Hardness test
4) Shape and size
5) Color test
6) Soundness test
7) Structure of brick

1) Absorption test on bricks

Absorption test is conducted on brick to find out the amount of moisture content absorbed by brick under extreme conditions. In this test, sample dry bricks are taken and weighed. After weighing these bricks are placed in water with full immersing for a period of 24 hours. Then weigh the wet brick and note down its value. The difference between dry and wet brick weights will give the amount of water absorption. For a good quality brick the amount of water absorption should not exceed 20% of weight of dry brick.

The water absorption of bricks after immersing 24 hours in water is given by

$$W = \frac{M_2 - M_1}{M_1} X\ 100$$

Where M1= weight of brick before immersing

M_2=weight of brick after immersing

Table: Water Absorption Test Results

Sl. No.	% of LPW and WSW added	Oven Dry wt. of specimen (M1)	Wet wt. of specimen (M2)	Water Absorption (%)
1.	0%	2.95	3.334	12.33
2.	5%	2.87	3.310	15.33
3.	10%	2.85	3.335	17.01
4.	15%	2.82	3.150	11.70

2) Crushing strength or compressive strength test on bricks

Crushing strength of bricks is determined by placing brick in compression testing machine. After placing the brick in compression testing machine, apply load on it until brick breaks. Note down the value of failure load and find out the crushing strength value of brick. Minimum crushing strength of brick is 3.50N/mm2.if it is less than 3.50 N/mm2, then it is not useful for construction purpose.

The compressive strength of bricks is given by

$$\text{Compressive strength} = \frac{\text{Maximum load at failure (N)}}{\text{Average area of bed face (mm}^2\text{)}}$$

Sl. No.	% of lime added	Avg. area of bed face (Cm2)	Compressive strength (kg/cm2)
1.	0%	410	35.5
2.	5%	410	36.5
3.	10%	410	37.1
4.	15%	410	35.9

3) Hardness test

In this test, a scratch is made on brick surface with the help of a finger nail. If no impression is left on the surface, the brick is sufficiently hard.

From the results of hardness test, as the percentage of lime added to bricks increases, hardness also goes on increases upto 10% after that at 15% hardness is decreased. This is because of percentage increase in lime will makes the brick brittle. This was clearly observed, at 15% of lime content, the scratch is easily made by finger nail.

4) Shape and size

In this test, a brick is closely inspected. It should be of standard size and its shape should be truly rectangular with sharp edges. For this purpose, 20 bricks of standard size (24cm x 15cm x 14cm) are selected at random and they are stacked lengthwise, along the width and along the height.

For good quality bricks, the results should be within the following permissible limits.

From the examination of bricks with increasing lime content, all bricks had clear shape and size.

5) Color test

A good brick should possess bright and uniform color throughout its body.

From the examination of bricks with increasing lime content, all bricks had same colour, with the increasing of lime content the reddish color turns into pale color

6) Soundness test

In this test, the two bricks are taken and they are struck with each other. The bricks should not break and a clear ringing sound should be produced.

From the examination of bricks for soundness test with increasing lime content, all bricks had better ringing sound.

7) Structure of brick

A brick is broken and its structure is examined. It should be homogeneous, compact and free from any defects such as holes, lumps, etc.

Randomly four bricks were selected from the group and the structure of each brick was examine.

5. Conclusion

Based on the result of both experimental and filed investigation on cement bricks and stabilized LPW and SWS bricks, the following concluding remarks can be drawn

- The physical and mechanical properties of brick tests with WSW and LPW are explored. The test comes about appear that the WSW and LPW combination gives comes about which are of potential to be utilized within the generation of lighter and conservative unused brick material.
- The perceptions amid the tests appear that the impact of 10–30% WSW substitutions in WSW and LPW lattice does not display a sudden delicate break indeed past the disappointment loads.

- The compressive quality of bricks increments with lime extent up to 10% after that in the event that the % of LPW & WSW increments the compressive quality diminishes
- Major utilization within the world for development is cement bricks; many researchers are by and by trying to find more current options because they require moo taken a toll materials, which are too naturally inviting. The method of fabricating cement bricks.
- LPW & WSW included cement squares incorporate; formally dressed building component sizes, utilize of locally accessible materials and lessening of transportation. Consistently, measured building components can result in less squander, quicker development and the plausibility of utilizing other pre-made components or secluded made building components.
- The utilize of common, locally-available materials makes great lodging accessible to more individuals, and keeps cash within the nearby economy instead of investing it on imported materials, fuel and substitution parts.

References

1. Elinwa AU, Mahmood YA. Ash from timber waste as cement replacement material. Cement and Concrete Composites. 2002;24(2):219-22.
2. Udoeyo FF, Dashibil PU. Sawdust ash as concrete material. ASCE, 0899-1561. 2002;14(2):173-6.
3. Li G, Yu Y, Zhao Z, Li J, Li C. Properties study of cotton stalk fibre/ gypsum composite. Cement and Concrete Research. 2003;33(1):43-6.
4. Soroushian P, Plasencia J, Ravanbakhsh S. Assessment of reinforcing effect of recycled plastic and paper in concrete. ACI Materials Journal. 2003;100-M23(3):203-7.
5. Galetakis M, Raka S. Utilization of limestone dust for artificial stone production: an experimental approach. Minerals Engineering. 2004;17:355-7.
6. Manning D. Exploitation and use of quarry fines. Report no. 087/ MIST2/DACM/01, 19 March 2004.
7. Shao Y, Lefort T, Moras S, Rodriguez D. Studies on concrete containing ground waste glass. Cement and Concrete Research. 2000;30:91-100.
8. Topcu IB, Canbaz M. Properties of concrete containing waste glass. Cement and Concrete Research. 2004;34:267-74.

9. Shayan A. Value-added utilisation of waste glass in concrete. Cement and Concrete Research. 2004;34:81-9.
10. Shi C, Wu Y, Riefler C, Wang H. Characteristic and puzzolanic reactivity of glass powders. Cement and Concrete Research. 2005;35:987-93.
11. Corinaldesi V, Gnappi G, Moriconi G, Montenero A. Reuse of ground waste glass as aggregate for mortars. Waste Management. 2005;25:197-201.
12. Aspiras FF, Manalo JR. Utilization of textile waste cuttings as building material. Journal of Materials Processing Technology. 1995;48(1-4):379-84.

Chapter - 5

Analysis of Newline Nano Engineered Hydrophobic Surfaces

Authors

K. Yugandhara Reddy
Research Scholar, Department of CIVIL Engineering, JNTUK, Kakinada, Andhra Pradesh, India

K.V.S.G. Murali Krishna
Professor & DAP, Department of CIVIL Engineering, JNTUK, Kakinada, Andhra Pradesh, India

Raja Reddy Duvvuru
Associate Professor, Malla Reddy Engineering College, Secunderabad, Telangana, India

Chapter - 5

Analysis of Newline Nano Engineered Hydrophobic Surfaces

K. Yugandhara Reddy, K.V.S.G. Murali Krishna and Raja Reddy Duvvuru

Abstract

Hydrophobicity means the tendency of a substance to repel water and to avoid wetting of surface. A surface is super hydrophobic if it has a water contact angle above 150°. These surfaces are water repellent. These surfaces with low contact angle hysteresis (less than 10º) also have a self-cleaning effect. Water droplets roll off the surface and take contaminants with them. Due to non-wetting of surfaces, hydrophobic surfaces have attracted much attention of researchers as there being potential applications in micro-fluidics, lab-on-chip, as functional surfaces and in self-cleaning of glasses and clothes, anti-snow sticking and monument protection are only some of them.

The self-cleaning surfaces are of interest in various applications, e.g., self-cleaning windows, windshields, exterior paints for buildings, navigation-ships and utensils, roof tiles, textiles, solar panels and reduction of drag in fluid flow, e. g. in micro/nano-channels. Also, super hydrophobic surface can be used for energy conservation and energy conversion. When two hydrophilic surfaces come into contact, condensation of water vapour from environment forms meniscus bridges at asperity contacts which lead to an intrinsic attractive force. This may lead to high adhesion. Therefore, super hydrophobic surfaces are desirable.

Keywords: Hydrophobic surfaces, contact angle, hierarchical microstructure

1. Introduction

Hydrophobicity refers to the non-wettability of surfaces, when they are in contact with a particular liquid. The surface has the property of repelling the liquid, instead of allowing it to become wet. Generally, in the study, the liquid is water and the wettability is in terms of effect of water droplet on the surface. On the other hand, if the surface allows wetting itself and liquid is not repelled, the surface is called to be a hydrophilic surface. The degree of hydrophobicity or hydrophillicity depends on a number of factors and conditions of surface texture, surrounding medium etc. It will be decided on the basis of contact angle made by the surface on the droplet, when the droplet sits on the surface. At a very high contact angle (>150°) the tendency of repelling the liquid is also high and sufficient to roll the droplet away at a very low angle of tilt, resulting in leaving without wetting the surface. Such surfaces are known as ‘Superhydrophobic Surfaces’ and the phenomenon as ‘Superhydrophobicity’. In case of liquid being oil, the surface with such property is known as ‘Superoleophobic’ Surface’. The phenomena of superhydrophobicity is covered and understood under the field of science known as “wetting” of solid surfaces by fluids and the history of the related research is over 200 years old. In year 1805, Thomas Young [10] and Pierre Simon de Laplace [11] propounded by intuition that an interface has a specific energy, the so-called interfacial energy, which is proportional to the number of molecules present at that interface and thus to the surface area of this interface [10-11]. From the shape of the drop sitting on a solid, Young determined the size of the solid/liquid contact in terms of the contact angle made by the liquid on the solid as shown in Fig.1. The contact angle (CA) that the fluid develops with its substrate, provides a complete description of the drop behavior in respect to its ability to spread on the solid substrate or not.

The above behavior at a solid/liquid interface has been studied since long as wetting science, as referred above. The wetting property of the solid surface is specified by the contact angle that a drop of fluid makes at the surface. The schematic in Fig.1 illustrates the wetting behavior of various solid surfaces in four classes, the contact angle (θ) defined by a fluid (here, water as fluid) droplet forms on the solid surface. A given solid substrate of certain surface free energy, will exhibit varied wetting property with varying contact angle for fluids of differing surface free energy or surface tension and the contact angle. The contact angle (CA) is a unit for measuring and specifying the wettability of surfaces. Basically, there are only two well-defined categories of wetting; the one of a CA of less than 90° when the fluid is attracted to spread on solid surface and the other with CA higher than 90° when the fluid is repelled to bead out to a spherical shape. One can see that wetting is a fundamental property of surfaces and can be central to innumerable natural processes as well as day-to-day human life and in industry.

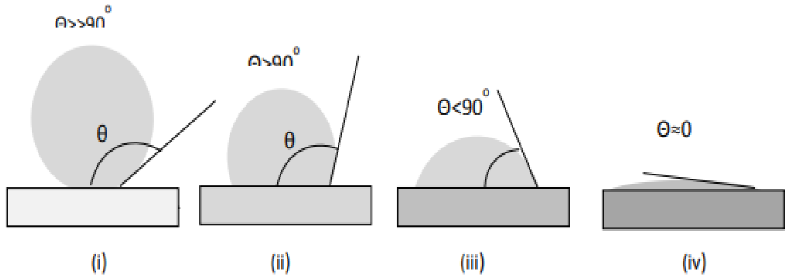

Fig 1: Schematic of various class of wetting; contact angle (CA) θ, for a water drop placed on surfaces of different hydrophobicities (i) highly hydrophobic, θ>>90°, for θ≥150° the surface may become superhydrophobic (ii) hydrophobic, θ>90° (iii) hydrophilic- θ.

Further, when the droplet rolls off easily from those superhydrophobic surfaces due to a small inclination < 10° of the surface, they are superhydrophobic and can provide a self-cleaning property similar to observed in lotus leaf. A schematic in Fig.1 demonstrates how the self cleaning is affected. The above definition of superhydrophobic surfaces with WCA ≥ 150° with SA.

1.1 Significance of superhydrophobicity to metals

Metals are important and indispensible materials. The innumerable applications of metals extend to most of the spheres of human activities from industrial, agricultural, structural, and scientific, to household consumer goods and utilities. Endowed with unique properties, the metals however present some limitations, for example, corrosion being one of them. Corrosion is a progressive and destructive process that compromises structural integrity and represents an enormous economic loss. Every year, the economic importance of rusting is such that it has been estimated that the cost of corrosion is over 1% of the world's economy. The corrosion by moisture and other harsh environment remains a matter of concern though protection of metal surface by coating the non-metallic materials has been commonly in practice, of course, with limited success. Perhaps, one of the most important applications for super hydrophobic surface is corrosion resistance for metals and alloys. In the past decade as the superhydrophobicity research progressed, super hydrophobic surfaces for metals have been an active area of research and development owing not alone to the potential that non-wetting ability holds for imparting anti-corrosion properties but also in enhancing the performance of metals.

1.2 The features on plant surfaces that help non-wetting

In respect to our interest in the present description related to hydrophobic or water repelling behavior of plant leaf surfaces, it is worthwhile to briefly explore their certain features relevant in the present context. The plants need a protective outer coverage to survive which is a continuous extracellular membrane, called cuticle. A schematic of outer protective layer of epidermis of a plant cell is shown in Fig.2 [7]. The referred protective layer is comprised of epicuticular wax tubules (epicuticular waxes can be of other morphology as well e.g., rod, tubules, platelets, hairs etc,) and the cutin backed with a pectin protein layer. Cutin performs a transpiration barrier function. The cuticle also serves as a multifunctional interface of nearly all primary tissues of land-living higher plants. One of the most important attributes of the cuticle is its hydrophobicity, which enables plants to overcome the physical and physiological problems connected to an ambient environment, such as desiccation. The protective outer coverage that as said above, is composed of hydrophobic material made basically of a polymer (cutin) and integrated or superimposed over it are the lipids usually referred as ‘‘waxes”.

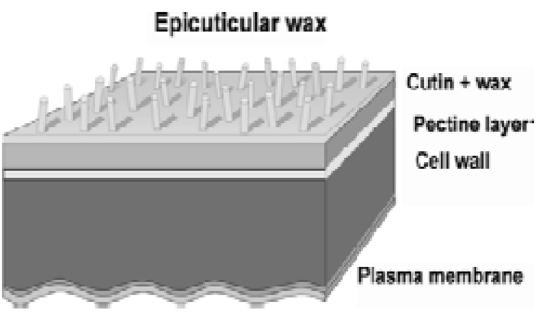

Fig 2: A simplified model of structure of the outermost layers

1.3 Lotus leaf surface: Hierarchical microstructure

The lotus leaf is one of the most well-known and studied examples of natural superhydrophobicity owing to its self-cleaning effect. For Lotus leaves, the static water contact angle is about 160° and hysteresis angle is < 4°. Raindrops roll easily across the lotus leaf surface, carrying away dirt and debris. The morphological characteristics of lotus leaves have been found to possess a hierarchical surface structure of convex nodules of micro scale papillae epidermal cells with a very dense arrangement of nano scale three-dimensional epicuticular waxes, where single or every epidermal cell formed a papilla. Hierarchical surface structures are formed by a combination of two structures in different sizes. A schematic model for hierarchical structure from the observed microscopic studies for lotus leaf can be represented as in Fig 3 [6-7]. These structural features appear akin to the features of outermost layer plant surface as shown and discussed earlier for Fig.3. The unique superhydrophobic and self-cleaning property of the lotus leaves has been attributed to the micro–nano scale hierarchical architectures in the form of the cilium-like nano -structures.

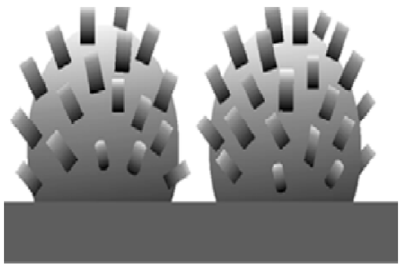

Fig 3: Schematic model of Hierarchical microstructure of super hydrophobic plant surfaces

2. Development of superhydrophobic steel

2.1 Methodology

A super hydrophobic structure, as discussed theoretically in essentially requires a dual/multiscale hierarchical structure. This inference has been drawn in past literature from observations on lotus leaf and many other natural plant and animal surfaces. A design concept for a potentially superhydrophobic surface based on the hierarchical nano/microstructure was proposed as described in chapter2. A large number of studies as surveyed in chapter 3 have established the concepts for creating the superhydrophobic surfaces by a variety of methods and using various material surfaces. The developing superhydrophobic stainless steel substrates have determined the optimal parameters of chemical (HF acid) etch showing that a microscale roughness could be created by a simple method. In this chapter we have determined optimal chemical etch method to get microscale roughness. It was also investigated by a model silica particle deposited surface to create nanoscale roughness. However, the criterion of superhydrophobicity namely, a Water contact angle of >150° and a contact angle hysteresis or the slide angle (SA) First, we create a microscale roughness on steel substrates using the methods. On so roughened surface, we deposit nanoscale silica SiO_2 particles. Expectedly, the microscale rough steel with nanoscale particles overlaid on its top may provide desired structure of hierarchical nature. This surface then can be treated by low surface energy fluro /chloro siloxane compounds or organosilanes as usual to obtain superhydrophobicity. The schematic of above proposed methodology is illustrated in Fig 5.

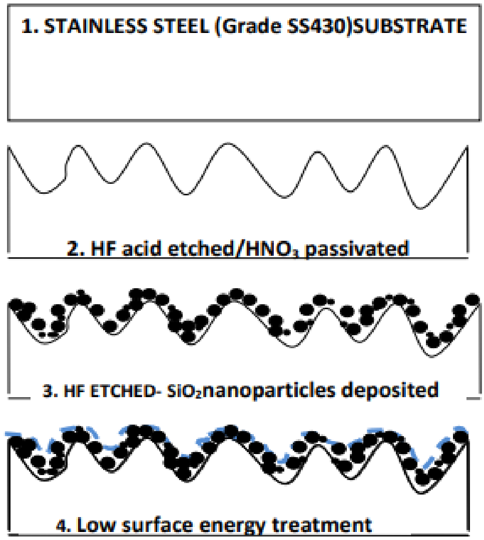

Fig 5: Preparing Superhydrophobic stainless steel surface (see text). 1. Substrate - Stainless steel Grade SS430, 2. The HF acid etched and HNO_3 acid passivated substrate to obtain microscale roughness, 3. Silica nanoparticles (black dots) deposited by colloidal self assembly on etched substrate to get a hierarchical nano/microstructure, 4. Low surface energy fluro/chloro compound treatment (in blue colour).

2.2 Low surface energy treatment

The method for coating the low surface energy is same as described the hydrophobicity agent fluoro carbon compound trichloro (1H,1H,2H,2Hperfluorooctyl) silane (PFOS). A diluted solution of PFOS 1-2 wt % in ethanol was prepared using magnetic- stirrer with the help of a magnetic-spin bar. The mixture of solvent fluoro compound was kept in capped bottles and vigorously stirred for 24 hours at room temperature. The etched and silica deposited SS specimen as prepared above were immersed for duration of 1hour and after withdrawing from solution were dried in oven at 70-80 °C. For adequate coverage of rough surface, the immersion dipping procedure was repeated for 2-3 cycles. Besides the fluro compound PFOS, we have also investigated three other chlorosilane compound as low surface energy coating for comparison of efficiency of flurosilanesand chlorosilanes. The following chlorosilanes are experimented:

TFPS [trichloro (3,3,3-trifluoropropyl) silane], DDTS (n-dodecyl trichlorosilane), and ODTS (octadecyl trichlorosilane). Now the used solvent for above chlorosilanes is n-hexane (in place of ethyl alcohol for the flurosilanes). As a result of soaking in a 5 mM solution of chlorosilane/n-hexane, a silyanatedhyrophobic layer was adsorbed onto the silica surface. After heat treatment at 150 °C for 1 hr and 220 °C for 5 min, a uniform layer of silylating agent was formed on the silica particle surfaces with the hydrophobic chains protruding outward. Using the above methods 4 numbers each of hierarchically structured and fluorinated/ chlorinated SS430 specimen were prepared. The process in brief for obtaining SiO_2-np: The tetraethylorthosilicate (TEOS) (6ml) (Sigma Aldrich) was added to the mixture of the co-solvent 80 ml ethanol (Merck), 4 ml DI water and 2.5 ml of saturated ammonia solution (28-30%) (Fisher Scientific). The mixture was stirred at 150 rpm for 2h at 35 °C using magnetic stirrer with a hot plate. The particle sizes were controlled by adjusting the pH from 9-9.5 by the ammonia catalyst and the cosolvent of the sol. The obtained milky solution, which contains the silica nano particle precipitate, was then added to the rotary evaporator (IKA- RV 10) at 60 °C and rotation speed of 120 rpm for around 40 minutes. To remove any residual solvents, nano particles were dried in vacuum at 70 °C overnight. After drying, the nano particle, were initially tested for extent of dispersion and for detecting heavier non dispersed particulates in acetone or ethyl alcohol. Whenever suspected, such particulates and agglomerate were removed by centrifuging at 2000rpm for 5-10 min and decanting the sol. The dried nano particles were washed and dispersed in ethanol typically using 5wt% SiO_2 in 30-50ml ethanol. The dispersion of colloidal SiO_2 kept in capped vial was ultrasonicated for about 10 minutes. The so dispersed sol was kept in an oil bath maintained at about 60 °C.

The etched and passivated SS430 substrate prepared earlier were dried in N2 and were dip coated using single dip coater (SDC 2007C, Apex instruments Co., India). The substrates were immersed in the dispersed silica sol kept in heated state as above and withdrawn. The dipping and withdrawal rate of 50 mm/min were used with holding time of 15 min immersion in the colloidal SiO_2 nano particle. The dip-coating was repeated for 3 cycles to get large area coverage by the siO_2 nano particles. In between the coating cycle, the substrate was allowed to cool at room temperature. The ethanol was allowed to evaporate by covering the vials with a petridish while avoiding convection cooling by the room temperature environment. The SS substrates with deposited silica are heated at 250-3000 °C in an oven for 4-6 hours for complete evaporation of solvent and also to help improve the adhesion of silica on the substrate by partial sintering.

3. Results and discussion of mono-modal silica surface

The object of Task2 has been to determine the nano roughness due to deposited SiO_2 nano particles for the purposes to create super hydrophobic steel. The SEM images of the SiO_2 nano particles deposited on the glass substrate are shown in Fig, respectively, for the targeted 80-100nm and 140-160nm diameter spherical particles. It is observed for both of these targeted dimensions SiO_2 particles, the particles are spherical. A small deviation has been noticed in diameters for both the cases of observed SEM images. The smaller dimensioned particles (80-100nm) in Fig.6 appear with smaller deviations in diameters, which is higher for larger dimensioned particles (140-160nm,). The results of dimensional analysis carried out with the help of image-pro software as described in the preceding section is revealed by the SEM image in Fig. It is clear that over 80% of the identified particles are measured approximately close to the targeted range of 80- 100nm. The prepared SiO_2 particles thus appear within reasonable error bars of ±10nm and are similar to abundant results in literature. The results of SEM images show well prepared spherical SiO_2 nano particles as meant for this investigation in Task.

Table 1: The solid fraction fs and theoretically predictable WCA, from CB equation\

Solid fraction, f_s	(1-f_s)	Cosθ_f^c	WCA θ_f^c
0.05	0.95	-0.9587	163.5
0.2	0.8	-0.8348	146.6
0.3	0.7	-0.7529	138.79
0.4	0.6	-0.6697	132.04
0.5	0.5	-0.5871	125.9
0.6	0.4	-0.5046	120.3
0.7	0.3	-0.4221	114.96
0.8	0.2	-0.3395	109.84

The theoretically predictable values of WCA, in equation for various solid fractions are tabulated in Table 1 and plotted in Fig.6 As expected, reduces as the solid fraction value increases as seen in the plot figure.

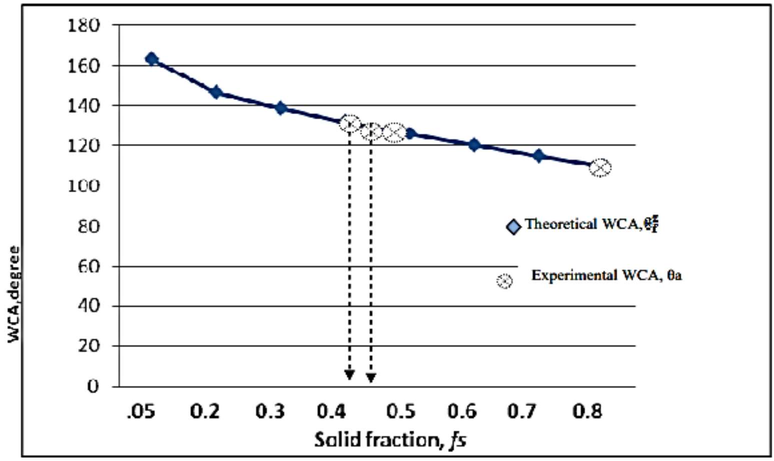

Fig 6: The theoretically predicted WCA, by Cassie-Baxter equation for solid-fractions

The chemical nature of prepared SS nano/micro-structured specimen has been examined by Fourier Transform Infra-red (FTIR) spectra. The FTIR spectra were recorded at room temperature with a Bruker spectrophotometer (model VERTEX-70). The experimental conditions were set to ensure a spectral resolution of 1 cm- 1. The FTIR for post low surface energy treated specimen have been obtained and presented in Fig 7.

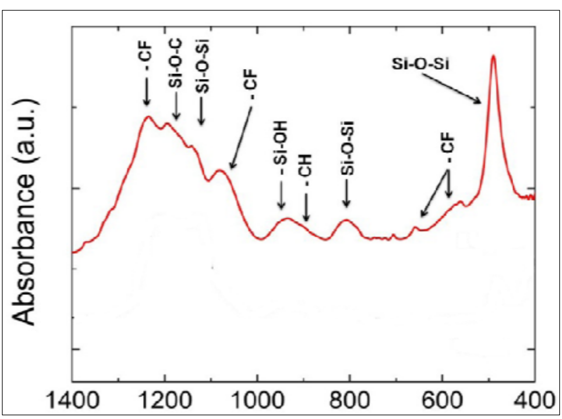

Fig 7: FTIR spectrum of Flurosilane (PFOS) treated SiO_2 nano particle surface

Conclusion

In industry, super-hydrophobic coatings are used in ultra-dry surface applications. The coating causes an almost imperceptibly thin layer of air to form on top of a surface. Super-hydrophobic coatings are also found in nature; they appear on plant leaves, such as the Lotus leaf, and some insect wings. The coating can be sprayed onto objects to make them waterproof. The spray is anti-corrosive and anti-icing; has cleaning capabilities; and can be used to protect circuits and grids. Super hydrophobic coatings have important applications in maritime industry. They can yield skin friction drag reduction for ships' hulls, thus increasing fuel efficiency. Such a coating would allow ships to increase their speed or range while reducing fuel costs. They can also reduce corrosion and prevent marine organisms from growing on a ship's hull.

References

1. Richard Denis, Christophe Clanet, David Quéré. Surface phenomena: Contact time of a bouncing drop. Nature. 2002;417(6891): 811-811

2. Yahua Liu, Lisa Moevius, Xinpeng Xu, Tiezheng Qian, Julia M Yeomans, Zuankai Wang *et al*. Pancake bouncing on superhydrophobic surfaces. Nature Physics. 2014;10:515-519.

3. Simpson John T, Hunter Scott R, Aytug Tolga. Superhydrophobic materials and coatings: a review". Reports on Progress in Physics. 2015;78(8):086501.Bibcode:2015RPPh...78h6501S. doi:10.1088/0034-4885/78/8/086501. PMID 26181655.

4. Meng Haifeng, Wang Shutao, Xi Jinming, Tang Zhiyong, Jiang Lei. Facile Means of Preparing Superamphiphobic Surfaces on Common Engineering Metals. The Journal of Physical Chemistry C. 2008;112(30):11454-11458. doi:10.1021/jp803027w.

5. Hu Z, Zen X, Gong J, Deng Y. Water resistance improvement of paper by superhydrophobic modification with microsized $CaCO_3$ and fatty acid coating. Colloids and Surfaces A: Physicochemical and Engineering Aspects. 2009;351(1-3):65-70. doi:10.1016/j.colsurfa.2009.09.036.

6. Lin J, Chen H, Fei T, Zhang J. "Highly transparent superhydrophobic organic–inorganic nanocoating from the aggregation of silica nanoparticles". Colloids and Surfaces A: Physicochemical and Engineering Aspects. 2013;421:51-62. doi:10.1016/j.colsurfa.2012.12.049.

7. Das I, Mishra MK, Medda SK, De G. Durable superhydrophobic ZnO–SiO_2 films: a new approach to enhance the abrasion resistant property of trimethylsilyl functionalized SiO_2 nanoparticles on glass (PDF). RSC Advances. 2014;4(98):54989-54997. doi:10.1039/C4RA10171E.

8. Torun Ilker, Celik Nusret, Hencer Mehmet, Es Firat, Emir Cansu, Turan Rasit *et al*. Water Impact Resistant and Antireflective Superhydrophobic Surfaces Fabricated by Spray Coating of Nanoparticles: Interface Engineering via End-Grafted Polymers. Macromolecules. 2018;51(23):10011–10020. Bibcode:2018MaMol..5110011T. doi:10.1021/acs.macromol.8b01808.
9. Warsinger David EM, Swaminathan Jaichander, Maswadeh Laith A, Lienhard V, John H. Superhydrophobic condenser surfaces for air gap membrane distillation. Journal of Membrane Science. Elsevier BV. 2015;492:578-587. doi:10.1016/j.memsci.2015.05.067. hdl:1721.1/102500.
10. Servi Amelia T, Guillen-Burrieza Elena, Warsinger David EM, Livernois William, Notarangelo Katie, Kharraz Jehad *et al*. The effects of iCVD film thickness and conformality on the permeability and wetting of MD membranes (PDF). Journal of Membrane Science, 2017.
11. Shang HM, Wang Y, Limmer SJ, Chou TP, Takahashi K, Cao GZ *et al*. Optically transparent superhydrophobic silica-based films. Thin Solid Films. 2005;472(1-2):37-43. Bibcode:2005TSF...472...37S. doi:10.1016/j.tsf.2004.06.087.
12. Never Wet Superhydrophobic Coatings - It Does Exactly What Its Name Implies (PDF). Truworth Homes. Retrieved 27 December 2019.
13. How to Apply Never Wet Rain Repellent. Rust-Oleum. 2 February 2016. Retrieved 27 December 2019 – via YouTube.
14. Dai S, Ding W, Wang Y, Zhang D, Du Z. Fabrication of hydrophobic inorganic coatings on natural lotus leaves for nanoimprint stamps. Thin Solid Films. 2011;519(16):5523. arXiv:1106.2228. Bibcode:2011TSF...519.5523D. doi:10.1016/j.tsf.2011.03.118. S2CID 98801618.
15. Kahn Mariam, Al-Ghouti Mohammad A. DPSIR framework and sustainable approaches of brine management from seawater desalination plants in Qatar. Journal of Cleaner Production. 2021;319:128485. doi:10.1016/j.jclepro.2021.128485.
16. Jump up to:a b McGuire, Michael F., Stainless Steel for Design Engineers, ASM International, 2008.
17. Ensikat Hans J. Superhydrophobicity in perfection: the outstanding properties of the lotus leaf, 2011.

18. Milionis, Athanasios; Loth, Eric; Bayer, Ilker S. (2016). "Recent advances in the mechanical durability of superhydrophobic materials". Advances in Colloid and Interface Science. 229: 57–79. doi:10.1016/j.cis.2015.12.007. PMID 26792021.