International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 09, September-2018

# Development and Evaluation of Vermiculite Tiles, Mortar and Concrete

Pannirselvam. N
Associate Professor,
SRM Institute of Science and Technology,
Kattankulathur.
Former Professor and Head of the Department,
Krishnasamy College of Engg. & Tech., Cuddalore, India

Santhoshini. R
Student of Undergraduate Program,
Krishnasamy College of Engg. & Tech.,
Cuddalore, India

***Abstract:*** **Heat inherited through the roof of the building is the major cause of unconditioned building or the major load for the air conditioned building. Vermiculite being a phyllosilicate group of hydrated magnesium-aluminium-iron silicate with the suggested formula of [(Mg, Fe, Al)$_3$(Al, Si)$_4$O$_{10}$ (OH)$_2$.4H$_2$O] is an inert material which resists the heat penetration. It is widely used as a filler material because of its low bulk density, high refractoriness, low thermal conductivity and adequate chemical inertness. This article mainly aims at the development and evaluation of vermiculite tiles which exhibits low water absorption, better strength properties and low heat penetration and better thermal insulation, when compared with traditional famous conventional tiles used for the flooring purpose. The usage of this material would decrease the structural weight. Various mixes were prepared using different percentage of vermiculite and water-cement ratio. The vermiculite tiles are light in weight which is easy to handle. The cement mortar cubes of dimensions 70.6 mm x 70.6 mm x 70.6 mm and mortar tiles of dimensions 304.8 mm x 304.8 mm x 6 mm were casted with replacement of fine aggregate with vermiculite in the ratio of 1:3 (C:F.A.). The fine aggregate was replaced with vermiculite in the fashion of 0.5 parts, 1 parts, 1.5 parts, 2 parts and 2.5 parts. The concrete cubes were casted in the dimensions of 150 mm x 150 mm x 150 mm with the mix ratio of 1:1.586:3.06 with the partial replacement of fine aggregate with vermiculite in the fashion of 50%, 75% and 80%.**

***Keywords: Better thermal insulation, Inertness, Light weight, Low heat penetration, Low water absorption, Reduced structural weight, Vermiculite tiles.***

## I.INTRODUCTION

Cost of energy and its crisis are alarming and adversely affecting the individual and the society in one form or the other. Thermal insulation (Barrier) has been considered as the best solution to reduce the energy load in individuals. Maximum heat transmission (more than 60%) takes place through roof surface of the buildings. Thermal insulations provides barrier for incoming heat into the building envelope and prevent inside heating. Use of thermally insulating materials impart comfort inside the room on one end and reduce the energy requirement for cooling in summer. Vermiculite is the key tool in considering energy thrifty buildings.

Fig. 1 Vermiculite

Vermiculite is an excellent mineral characterized by the high thermal insulation parameters which make it useful for many purposes, including those for manufacturing different kinds of fire-proofing materials as well as production of boards. Vermiculite occurs as golden-brown to greenish flakes. As a mineral it is distinguished by an outstanding ability to gain in volume (10-30 times) when exposed to high temperatures. This phenomenon is accompanied by water loss. Its bulk density in the natural form is between 600 and 1050 kg/m$^3$ and after swelling 65-130 kg/m$^3$. Because of low density, it is mainly used in expanding form.

Exfoliated vermiculite is also characterized by the properties of good sound insulation, good thermal insulation and good adhesion to different kinds of surfaces. Non-combustible vermiculite products emit neither smoke nor toxic fumes and make no hazard to the environment. Vermiculite is formed by hydration of certain basaltic minerals. Its moulded shapes, bonded with sodium silicate is used in high temperature insulation, refractory insulation, packing material, fire proofing of structural steel and pipes, as loose fill insulation, light weight aggregate for plaster and cementitious spray fire proofing.

Vermiculite is a rich mineral which is well known for its ability of exfoliation which expands rapidly when it is heated. It is categorized based on its grades, density and many factors which are broadly classified into crude and exfoliated vermiculite but vermiculite is mostly used in exfoliated form that serves various applications.


(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 09, September-2018

Approximately 25-30% of the total energy consumption in the world is used in buildings. About 80% of the energy consumed in commercial and residential buildings is used for space heating and cooling. An important way of achieving better energy efficiency in buildings is to improve their thermal insulation properties. Reduction of the heat loss in building decreases the consumption of energy and, thus, reduces the cost if heating and cooling. Enhanced thermal protection is a therefore a prerequisite to construct or rehabilitate buildings to reach a reasonable energy consumption, satisfactory thermal comfort conditions, and low operational costs. Energy saving can be obtained by insulation since a significant part of heat losses or heat gains occurs through walls and ceilings.

An analysis of conduction heat transfer through structure is of great importance in civil engineering problems, such as heat flow into a building in energy-efficient building design, thermal loading of structures due to diurnal variations of temperature, planning and design of building for thermal comfort, design of radiation shields in nuclear power stations, analysis of bridge deck and other exposed structures for solar thermal loading, etc.

## II.MATERIALPROPERTIES

### *A. Cement*

The chemical and physical properties of the Portland Pozzolona Cement are given in the table 1 & 2.

Table 1 – Chemical properties of the cement

| Sl. No. | Composition | Percent |
|---|---|---|
| 1. | $SiO_2$ | 19.4 |
| 2. | $Al_2O_3$ | 5.6 |
| 3. | $Fe_2O_3$ | 2.4 |
| 4. | CaO | 63.1 |
| 5. | MgO | 2.6 |
| 6. | $SO_3$ | 2.9 |
| 7. | $Na_2O$ | 0.8 |
| 8. | $K_2O$ | 1 |
| 9. | CI | 0.01 |
| 10. | Insoluble material | 3.3 |
| 11. | Loss on ignition | 3.3 |

Table 2 – Physical properties of cement

| Sl. No. | Description | Value | Remarks |
|---|---|---|---|
| 1. | Specific gravity | 3.10 | Tested results are satisfactory as per IS 1489 part-1 (1991) |
| 2. | Consistency | 33% | |
| 3. | Initial setting time | 40 mins. | |
| 4. | Final setting time | 350 mins | |
| 5. | Soundness | 10 mm | |
| 6. | Fineness | 10% | |

### *B. Fine Aggregate*

The physical properties of fine aggregate and vermiculite that are used in the manufacture of vermiculite tiles, mortar and concrete are presented in table 3 & 4.

#### *1) River Sand*

Table 3 – Physical Properties of fine aggregate

| Sl. No. | Description | Value |
|---|---|---|
| 1. | Specific Gravity | 2.5 |
| 2. | Fineness Modulus | 5.495 |
| 3. | Bulk Density | 1648 kg/m$^3$ |
| 4. | Dry Density | 1575 kg/m$^3$ |
| 5. | Zone | II |

#### *2) Vermiculite*

The vermiculite is a highly thermal insulating material which can be used as a filler material in the concrete for avoiding the effect of heat inheritance in the roof of the building.

Table 4 – Physical properties of Vermiculite

| Sl. No. | Description | Value |
|---|---|---|
| 1. | Fineness Modulus | 6.965 |
| 2. | Specific Gravity | 1.1 |
| 3. | Bulk density | 388 kg/m$^3$ |
| 4. | Dry Density | 607 kg/m$^3$ |

### *C. Coarse Aggregate*

The proportioning of coarse aggregate 60% of 20 mm and 40% of aggregate greater than 12.5 mm is used in the concrete. The physical properties of the coarse aggregate are given in table 5.

Table 5 – Physical properties of coarse aggregate

| Sl. No. | Description | Value |
|---|---|---|
| 1. | Fineness Modulus | 4.91 |
| 2. | Specific Gravity | 2.65 |
| 3. | Water absorption | 0.35% |

## III. MIX PROPORTIONS FOR SPECIMENS

### *A. Vermiculite Mortar Cubes and Tiles*

The vermiculite mortar cubes were prepared in the ratio of 1:3 with the partial replacement of river sand by vermiculate in the following mix ratios in table 6. The mortar cubes were casted by considering both volume batching and weight batching.

Table 6 - Vermiculite Mortar Cubes (Vol., wt. batching) and tiles

| Sl. No. | Mix Proportion | Ratio |
|---|---|---|
| 1. | C:S | 1 : 3 |
| 2. | C:VM | 1 : 3 |
| 3. | C:S:VM | 1 : 0.5 : 2.5 |
| 4. | C:S:VM | 1 : 1 : 2 |
| 5. | C:S:VM | 1 : 1.5 : 1.5 |
| 6. | C:S:VM | 1 : 2 : 1 |
| 7. | C:S:VM | 1 : 2.5 : 0.5 |


(This work is licensed under a Creative Commons Attribution 4.0 International License.)

*B) Vermiculite Concrete*

The vermiculite concrete was casted in the grade $M_{20}$ with mix ratio of 1:1.586:3.06.

Table 7 – Vermiculite Concrete

| Sl. No. | Percentage of Sand and VM |
|---|---|
| 1. | Conventional Concrete (100% sand and 0% VM) |
| 2. | 50% Sand , 50% VM |
| 3. | 75% Sand , 25% VM |
| 4. | 80% Sand , 20% VM |

## IV.CASTING OF SPECIMENS

1. The vermiculite mortar cubes were casted in the cube moulds of dimension 70.6 mm x 70.6 mm x 70.6 mm.
2. The vermiculite concrete cubes were casted in the cube moulds of dimension 150 mm x150 mm x150 mm.
3. The vermiculite tiles were casted in the mould of dimension 304.8 mm x 304.8 mm x 6 mm.

Fig. 5. – Mixing of specimens

Fig. 6. – Mortar Cubes (70.6 mmx70.6 mmx70.6 mm)

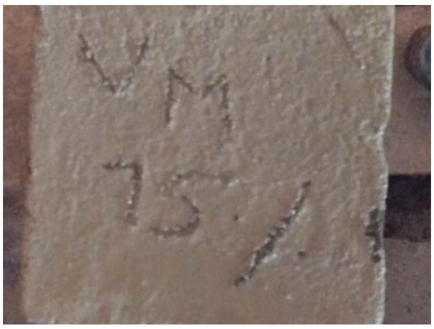

Fig. 7. – Concrete Cubes (150 mmx150 mmx150 mm)

Fig. 8. – Vermiculite Tiles (304.8 mm x 304.8 mm x 304.8 mm)

## V. RESULT AND ANALYSIS

The casted specimens after 3, 7, 14 and 28 days of curing are subjected to the following test:

- Compression Test
- Durability Test
- Thermal Conductivity test.

*A. Compression Test*

1). *Mortar Cubes (Weight Batching)*

Table 8 Compressive strength for wt. batched cubes in $N/mm^2$

| Ratio | 3 Days | 7 Days | 14 Days | 28 Days |
|---|---|---|---|---|
| C:S 1:3 | 12 | 23.5 | 34 | 43.5 |
| C:VM 1:3 | 0.8 | 0.8 | 0.8 | 1.0 |
| C:S:VM 1:0.5:2.5 | 1 | 1 | 1 | 1.2 |
| C:S:VM 1:1:2 | 1.2 | 1.4 | 1.8 | 2.4 |
| C:S:VM 1:1.5:1.5 | 1.4 | 1.6 | 2.0 | 3.0 |
| C:S:VM 1:2:1 | 1.6 | 1.8 | 2.2 | 3.4 |
| C:S:VM 1:2.5:0.5 | 2.2 | 3.4 | 4.6 | 5.8 |

2). *Mortar Cubes (Volume Batching)*

Table 9 – Compressive strength for volume batched cubes

| Ratio | 7 Days | 28 Days |
|---|---|---|
| C:S 1:3 | 23.47 | 43.54 |
| C:VM 1:3 | 3 | 3.6 |
| C:S:VM 1:0.5:2.5 | 3.6 | 4.0 |
| C:S:VM 1:1:2 | 3 | 4.4 |
| C:S:VM 1:1.5:1.5 | 3.41 | 6.01 |
| C:S:VM 1:2:1 | 6.62 | 9.02 |
| C:S:VM 1:2.5:0.5 | 9 | 12.23 |


(This work is licensed under a Creative Commons Attribution 4.0 International License.)

3). *Concrete Cubes*

Table 10 – Compressive strength for concrete cubes

| Ratio | 7 Days | 28 Days |
|---|---|---|
| Conventional Concrete | 26.49 | 31.91 |
| 50% Sand, 50% VM | 8.71 | 10.08 |
| 75% Sand, 25% VM | 12.22 | 17.15 |
| 80% Sand, 20% VM | 10.8 | 14.3 |

B). *Thermal Conductivity (TC)Test*

1) *Mortar Cubes (Weight Batching)*

Table 11 – TC for weight batched mortar cubes

| Sl. No. | Ratio | Temp. |
|---|---|---|
| 1. | 1 : 3 | 32.61 |
| 2. | 1 : 3 | 21.26 |
| 3. | 1 : 0.5 : 2.5 | 22.69 |
| 4. | 1 : 1 : 2 | 23.86 |
| 5. | 1 : 1.5 : 1.5 | 23.08 |
| 6. | 1 : 2 : 1 | 24.39 |
| 7. | 1:2.5:0.5 | 25.92 |

2) *Mortar Cubes (Volume Batching)*

Table 12 – TC for weight batched mortar cubes

| Sl. No. | Ratio | Temp. |
|---|---|---|
| 1. | 1 : 3 | 32.54 |
| 2. | 1 : 3 | 24.10 |
| 3. | 1 : 0.5 : 2.5 | 24.54 |
| 4. | 1 : 1 : 2 | 24.67 |
| 5. | 1 : 1.5 : 1.5 | 25.09 |
| 6. | 1 : 2 : 1 | 25.35 |
| 7. | 1:2.5:0.5 | 25.43 |

3) *Vermiculite Tiles*

Table 13 – TC for volume batched mortar cubes

| SL. NO. | RATIO | STRENGTH | TEMP. |
|---|---|---|---|
| 1. | 1 : 3 | 9.84 | 30.26 |
| 2. | 1 : 3 | 2.46 | 21.16 |
| 3. | 1 : 0.5 : 2.5 | 4.37 | 21.65 |
| 4. | 1 : 1 : 2 | 5.47 | 22.65 |
| 5. | 1 : 1.5 : 1.5 | 6.56 | 23.12 |
| 6. | 1 : 2 : 1 | 6.56 | 23.69 |
| 7. | 1:2.5:0.5 | 8.20 | 25.03 |

4) *Concrete Cubes*

Table 14 – TC for concrete cubes

| Sl. No. | Ratio | Temp |
|---|---|---|
| 1. | 100% S, 0% VM | 36.25 |
| 2. | 50% S, 50% VM | 23.62 |
| 3. | 75% S, 25% VM | 24.14 |
| 4. | 80% S, 20% VM | 25.98 |

## VI CONCLUSION

The developed high-temperature heat-insulating cement-based materials produced by using expanded vermiculite can be used in thermal power plants with the hot-wall temperature as an alternative to lightweight chamotte components and fibrous heat insulators. Since the mix ratios are one of the significant parameters influencing the strength and the thermal conductivity of cement-based composites, results of the TC and strength as a function these parameters were compiled. Thermal conductivity decreased by the increase in the content of the expanded vermiculite in the mix. The thermal conductivity for the specimens with complete replacement of river sand by expanded vermiculite was observed to be lower than the other specimens with partial replacements. The development of the models based on the existing experimental data was carried out to predict material properties for the design of the composite materials.

In order to develop or increase the performance of similar materials in the future, mix proportions may be optimized by taking into account different mix proportions and curing conditions. Cement based material produced by expanded vermiculite can be used as a new material and structural component with good physical material properties for housing and other structures. Composites to be produced with expanded vermiculite may become viable and promising construction material for the point of view of energy conscious and ecological design in the future. The self weight of the concrete is also reduced by the incorporation of the expanded vermiculite in the concrete composite.

The vermiculite concrete tends to show better strength properties when the river sand is replaced by 25% when compared with the other proportions. The graph for strength values of the vermiculite concrete is found to be lower for the 50% replacement of the river sand and tends to increase further for 25% replacement and drops gradually for the 20% replacement of river sand by the expanded vermiculite. While the graph for the thermal insulation of the specimens increased with the increase in the content of expanded vermiculite. The strength parameters and the thermal conductivity of the vermiculite composites for both mortar cubes and concrete cubes tends to decrease with the increase in the content of expanded vermiculite.

The heat in the roof of the building can be reduced to a great extent by incorporating the expanded vermiculite and the required strength can be achieved by adding considerable amount of admixtures to the composites. Vermiculite tiles exhibits low water absorption, better strength properties and low thermal conductivity which can be used in roof slab of the buildings, computer rooms and cold storages, etc. The shrinkage and creep resistance is one of the greater advantages


(This work is licensed under a Creative Commons Attribution 4.0 International License.)

in vermiculite tiles and the concrete and it does not undergo any chemical reaction with concrete and it is eco-friendly.

ACKNOWLEDGEMENT

The authors thank TNSCST for the grant provided to carry out the project and the authors also thank the management of Krishnasamy College of Engg. & Tech., for their constant support and encouragement in carrying out this project.

REFERENCES

[1] Divya M.R., Prof. M. Rajalingam, Dr. Sunitha George, "Study on concrete with replacement of fine aggregates by vermiculite", ISSN:2454-4116, Vol. 2, Issue-5, May 2016 Page 87-89.

[2] Elbehiery. H.M.;, Hefnawy, A.A.; Elewa, M.T. "Quality control enhancement via non-destructive testing for green ceramic tiles" Circuits and Systems, 2003 IEEE 46th Midwest Sympsoium on Volume: 3 DOI: 10.1109/MWSCAS.2003. 1562492 Publication Year: 2003, Pages: 1130-1133 Vol. 3.

[3] Henglong Zhang, Hongbin Xu, Xiaoliang Wang, Jianying Yu "Microstructurs and thermal aging mechanism of expanded vermiculite modified bitumen" Construction and Building materials, Volume 47, October 2013, Pages 919-926.

[4] Karla Cech Barabaszova, Marta Valaskova "Characterization of vermiculite particles after differnet milling techniques" Powder Technology, Volume 239, May 2013, pages 277-283.

[5] Olaowebikan Folorounwo, Christopher Dodds, Georgios Dimitrakis, Samuel Kingman "Continuous energy efficient exfoliation of vermiculite through microwaveheating". International Journal of Mineral Processing, Volumes 114-117, 21 November 2012, pages 69-79.

[6] Osman Gencel, Juan Jose del Coz Diaz, Mucahit Sutcu, Fuat Koksal, F.P. Alvarez Rabanal, Gonzalo Martinez-Barrera, Witold Brostow "Properties of gypsum composites containing vermiculite and polypropylene fibres: Numerical and experimental results". Elsevier, 70(2014) 135-144.

[7] O. Gencel, F.Koksal, M. Sahin, M.Y. Durgun, H.E. Hagg Lobland, and W. Brostow, "Modeling of thermal conductivity of concrete with vermiculite by using artificial neural networks approaches", ISSN: 0891-6152, 26:360-383, 2013.

[8] Praveen Kumar. E, Manojjkumar. C, Prakash K.B., Siddesh K. Pal, "Experimental study on vermiculite insulated samples with conventional samples in construction industry", IJRET, Vol. 04, Issue:02/Feb-2015, 615-622.

[9] Rajini Lakhani, S.P. Agharwal, Sapna Ghai & R/K. Saxena "Vermiculite cement mortar for thermal insulation", CSIR, Roorkee 247 667 (UK), December 2013.

[10] Syed Abdul Rahman. S, Gijo K Babu, " An Experimental Investigation on Light Weight CementConcrete using Vermiculite Minerals", International Journal of Innovative Research in Science, Engineering and Technology DOI:10.15680/IJIRSET.2016.0502156. Vol. 5, Issue 2, February 2016, 2389-2392.

[11] Xiang Li, Bingrong Lei, Zhidan Lin, Langhuan Huang, Shaozao Tan, Xiang Cai "The utilization of organic vermiculite to reinforce wood-plastic composites with higher flexural and tensile properties" Industrial crops and Products, Volume 51, November 2013, Pages 310-316.

[12] Indian Minerals Year book – 2013 (Part III: Minerals Review) 52nd edition, Vermiculite Advanced release.

[13] IS 456-2006: Indian Standard PLAIN AND REINFORCED CONCRETE – CODE OF PRACTICE (Fourth Revision).

[14] IS 654–1992 (Reaffirmed 2002): Indian Standard CLAY ROOFING TILES, MANGLORE PATTERN – SPECIFICATIONS (Third Revision).

[15] IS 1489 (Part I): Indian Standard PORTLAND POZZOLONA CEMENT (fly ash based).

[16] IS 2858 – 1984 (Reaffirmed 2000):Indian Standard CODE OF PRACTICE FOR ROOFING WITH MANGLORE TILES (First Revision).

[17] IS: 10262–1982 THE RECOMMENDED GUIDELINES FOR CONCRETE MIX DESIGN, Bureau of Indian Standards, New Delhi, 1998.

[18] IS 13630 (Parts 1 to 15) 2006: Indian Standard CERAMIC TILES – METHODS OF TEST, SAMPLING AND BASIS FOR ACCEPTANCE (First revision).

[19] IS 13712 2006: Indian Standard CERAMIC TILES – DEFINITIONS, CLASSIFICATIONS, CHARACTERISTICS AND MARKING (First Revision).

[20] "The Vermiculite Association" Kingsley House, Ganders Business Park, Kingsley.

[21] Shetty M.S., "Concrete Technology", S. Chand and /company Ltd., New Delhi, 2003.

[22] Gupta B.I., Amit Gupta, "The Concrete Technology", Jain Book Agency, 2010.


(This work is licensed under a Creative Commons Attribution 4.0 International License.)