# Utilization of Bentonite in Concrete: A Review

**M. Achyutha Kumar Reddy, V.Ranga Rao**

***Abstract:*** ***Production of cement generates huge amount of $CO_2$ into the environment. Utilization of pozzolanic materials in concrete will be a better solution for this problem. Several studies were available for utilization of fly ash, Ground Granular Blast Furnace Slag (GGBS), Metakaolin and silica fume as a pozzolanic material in concrete. A few literatures were available on bentonite as a construction material in concrete. Bentonite is a clay contains silicain rich amounts, obeys the pozzolanic properties. This paper presents the overview of research work presented on physical, chemical, performance in cement mortars like consistency, setting times & compressive strength, properties of fresh & hardened concrete like workability, compressive strength, split tensile strength, flexure strength made by the bentonite as partial substitution of cement in concrete.***

***Index Terms: Cement Production, pozzolanic materials, bentonite, strength & durability.***

## I. INTRODUCTION

Hydraulic cement utilization in concrete grown rapidly in recent years. Production of cement causes about 7% of entire globe $CO_2$ emissions, particularly in clinker production [1]. The bring down of cement usage in concrete was needed to minimize $CO_2$ emissions into environment. Pozzolanic materials utilization will reduce the hydraulic cement usage in concrete. Usage of Industrial wastes like fly ash, GGBS, Silica fume etc. as substitute material to cement will reduce the cement usage in concrete [2]. Now-a-days fly ash utilization in concrete became very common practice. Coal based thermal power plants generates most of the fly ash [3]. Unit cost of electricity generation is very high through thermal power plants comparatively than other sources (renewable-energysources.com). Thermal power plants produce huge amount of $CO_2$ emissions into environment. The production of fly ash causes damage to the environment. Finding of natural pozzolans is needed which will not harmful to environment.

Few research works were done by utilization of bentonite as partial substitution of cement in concrete. This paper reports the overview of the bentonite utilization in cement mortar as well as concrete.

## II. BENTONITE

Bentonite is a clay mineral which exhibit little bit swelling behavior as well as obeys Pozzolanic properties [4],[5]. Large quantities of bentonite resources are available throughout the world [6]. It has major applications in fields like drilling fluids, foundry bonds, absorbents, adhesives, bleaching earths, ceramics etc. [7]&[8]. J. Mirza Initiated the research work by using bentonite as substitute material to cement in concrete in 2009. Plenty of investigations were carried out by researchers from different locations throughout the globe. They reported some facts related to bentonite utilization based on the experimental results. Majority of the authors used Pakistani bentonite available from different locations of Pakistan. [10-12] employed Jahangira bentonite, [9] used Karak bentonite, [13]&[14] utilized Khyber bentonite, [15]&[16], used Telangana bentonite &[17] employed bentonite from Amazon region Brazil.

### *A. Physical Properties*

Bentonite is generally available in various colors and forms. A Few authors reported about the color, [9] - greenish gray & browning green, [12] - light yellow colored bentonite was of bentonite utilized in research work. Table I shows the over view of physical properties of bentonite reported by some authors. Almost all authors reported different values. The reason behind this attribute to change in location of source.

### *B. Chemical properties*

Chemical composition of cement shows tremendous effect on mechanical properties of concrete [31]. Table II shown the review on chemical properties of bentonite. Majority of authors reported higher amount of $SiO_2$ presence$Al_2O_3$accomplish as second major element in bentonite. These leads to occurrence of pozzolanic reaction while hydration process. Chemical properties as per ASTM C618, most of the authors reported as within the limits. 13.74.

## III. BENTONITE BEHAVIOR IN CEMENT MORTARS

A few authors reported the behavior of bentonite in cement mortars like normal consistency, initial & final setting times, strength activity index, and compressive strength.

### *A. Normal consistency*

Bentonite exhibits 75% as normal consistency value whereas OPC attains at 30 – 35% [15], 21 percentage bentonite-OPC mixture attains 35% consistency was reported by [10].However, it was observed that the normal consistency is directly proportional to bentonite addition.

Revised Manuscript Received on December 22, 2018.

**M. Achyutha Kumar Reddy,** Research Scholar, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, A.P., India.

**V. Ranga Rao,** Professor, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, A.P., India.

**Table I: Physical properties of bentonite used in various research works**

| Property | [10] | [9] | [11] | [18] |
|---|---|---|---|---|
| Specific Gravity | 2.82 | 2.63 | 2.44 | 2.79 |
| Average particle size | 4.75 µm | 17% retained on # 325 mesh | 13.5% retained on # 325 mesh | 4.32 µm |
| Blains fineness ($cm^2/gm$) | 4800 | -- | 2689 | 4800 |

**Table II: Chemical properties of bentonite used in various research works**

| Property | [10] | [9] | [11] | [12] | [14] | [15] |
|---|---|---|---|---|---|---|
| Silicon dioxide ($SiO_{2)}$ | 54.55 | 49.44 | 65 | 49.63 | 52.1 | 51.11 |
| Aluminum Oxide ($Al_2O_3$) | 20.19 | 19.7 | 15 | 21.11 | 13.4 | 16.83 |
| Ferric Oxide ($Fe_2O_3$) | 8.60 | 6.2 | 3 | 3.23 | 7.5 | 7.65 |
| Megnesium Oxide (MgO) | 4.20 | 1.61 | 6.5 | 12.56 | 2.64 | 7.57 |
| Calcium Oxide (CaO) | 7.28 | 7.45 | 2.66 | 3.59 | 12.0 | 6.60 |
| Sodium Oxide ($Na_2O$) | 1.27 | 0.87 | 0.12 | 0.44 | - | 0.29 |
| Potassium Oxide ($K_2O$) | 3.92 | 0.63 | 0.27 | 2.09 | 2.64 | 1.34 |
| Phosphorus pentoxide ($P_2O_5$) | 1.107 | - | - | 0.11 | - | 0.29 |
| Titanium Oxide ($TiO_2$) | 0.91 | - | - | 0.49 | - | 1.29 |
| Loss on Ignition (LoI) | 5.42 | 13.74 | 6 | - | 8.61 | 6.75 |

*B. Initial & final setting time*

Initial & final setting time test was performed as per standard procedure IS: 4031.Bentonite exhibits 68 & 190 minutes where shown OPC 43 & 125 minutes after addition with water [15]. Initial & final setting times increasing by addition bentonite to cement.

*C. Strength activity Index (SI)*

J. Mirza, 2009 conducted several tests on SI as per standard procedure ASTM C618for bentonite mixes at different temperatures [9]. Higher SI was observed in $150^oC$ heated bentonite comparatively with other temperatures.S ahmad, 2011 reported 87.3 & 85. 23 percent SI for bentonite at the age of 7 & 28 days. 3% bentonite-cement mixes shown better SI at 7days, remain mixes up to 21% exhibits best SI comparatively among all mixes [11].

*D. Compressive strength (CS)*

J. Mirza conducted tests as per standard procedure ASTM C109, reported that $150^0C$ heated 20 percent bentonite-cement mixes attains good CS at the age of 7 & 28 days remaining mixes shown lower CS than control cement mortar [9]. S. Ahmad, 2011 conducted experiments on bentonite mixes at room temperature & $500^0C$, all mixes shown lower CS than control mix. 30% bentonite-cement mixes shown higher resistance to $MgSO_4$& $Na_2SO_4$[11]. G. V. Reddy, 2017 reported 20 % bentonite-cement mix shown optimum CS after 3, 7 & 28 days curing among all mixes [15].

## IV. BENTONITE BEHAVIOR IN FRESH CONCRETE

H. H. Murry, 2006initiates 1-2 % addition of sodium bentonite improves the workably as well as segregation of concrete, plenty investigations made after this to measure exact workability [7].

*A. Workability*

Drastic decrease in workability was observed at higher percentages (minimum of 20%) of bentonite substitution in concrete [9], [11]. Bentonite utilization was done in lower percentages (0-21 at 3% interval) by S. A. Memon, 2012, he recommended utilization of super plasticizer needed to enhance workability [10].

*B. Fresh concrete density*

Density of fresh concrete was examined by standard procedure ASTM C642, decreasing by addition of bentonite to concrete [10].


Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

## V. BENTONITE BEHAVIOR OF HARDENED CONCRETE.

Plentyauthors reported the effect of bentonite on mechanical properties of hardened concrete. Compressive strength was determined at different ages of concrete. Resistance of concrete was tested and reported under various climatic conditions.

### *A. Strength of concrete*

Majority of authors reported that lower strengths were observed by addition of bentonite at early ages (3,7 & 28 days), better performance shown at later ages (56 & 90) of curing comparatively with control concrete.

***Compressive strength (CS):*** J. Mirza, 2009 performed tests by varying bentonite (0-50%) at room temperature and heated at $150^0$C for 3 hours, S. Ahmad, 2011 investigates bentonite heated at $500^0$C [9]. They reported that 20% of bentonite (heated at $150^0$C for 3 hours) substituted concrete mixes exhibit better CS at 28 days curing among all [11]. The CS of concrete is directly proportional to the temperature at which bentonite was heated for 3 hours. R. A. Khushnood, 2014 reported heated bentonite blended concrete mixes shown higher CS than raw bentonite [18]. S A Memon, 2012examined up to 21% bentonite substitution, reported that lower CS exhibits at the age of 3, 7day, better CS shown at 28, 56 days after curing. Junaid Akabr, 2013 investigates at 20% bentonite substitution, poor CS results were reported when comparing with control mix [12].

G V Reddy, 2017 used 10-30% of bentonite substitution at 5% interval, tests were conducted as per standard procedure IS:516, reported that lower CS were observed for blended mixes among all [15].M. Karthikeyan, 2015 reported that 30% of bentonite replacement results higher CS than control mix. R Divyana, 2015 & J M A Kadar, 2016 reported that 20% bentonite substitution shown greater CS than control mix [20], [21]. J Chamundeswari, 2012 & R Selvaraj, 2015 reported that bentonite addition decreases in CS of concrete [22], [23]. M. Chandraskanth, 2016 suggests 5% bentonite addition attains maximum CS to the concrete [24]. M. Aravinda Raj, 2016 suggested that 15-50% bentonite-quarry dust mixture exhibits maximum CS at the age of 28 days [25]. M E Shabab, 2016 investigates about bentonite-fly ash mixes, reported that the concrete contains equal combination (50-50%) of bentonite and fly ash exhibits better results at the age of 90 days [14].

***Split tensile strength (STS):*** M. Karthikeyan, 2015 reported that 30% substitution of bentonite results maximum STS to concrete [19]. G V Reddy, 2017 conducted experiments as per standard procedure IS5816, reported that lower STS were observed in bentonite blended mixes [15].Divyana, 2015 reported better STS was attained by 20% bentonite replacement [20]. J Mohammad, 2007 tested on bentonite-steel slag mixture with various proportions, reported that 20-60% bentonite-steel slag mixtures [26]. M. Chandra Kanth, 2016 reported 5 % bentonite addition improves results STM of concrete [27].

***Flexure strength (FS):*** J Mirza, 2009 & R A Khushnood, 2014reported that no change in FS was observed by heated bentonite over raw bentonite, decrease in FS was reported by addition of bentonite to concrete [9] & [18]. M. Karthikeyan, 2015 reported that little increment in FS upon bentonite addition, 30% substitution exhibits maximum FS among all combinations [19]. M. Chandra Kanth reported 5% of bentonite addition improves FS of concrete [27].

***Water absorption:*** No effect of bentonite substitution was reported by all most all authors [9]&[14]. S A Memon, 2012 reported that decrease in water absorption by increasing percentage of bentonite blending [10].

### *B. Durability of concrete*

Durability displays crucial role in when concrete is exposed to extreme conditions [31].A few investigations were done on durability of bentonite blended concrete like sulphate attack, acid attack & salt attack. S A Memon, 2012 tested bentonite blended concrete (0-21% @3 interval) against to hydrochloric acid & Sulfuric acid [11]. They reported that resistance is directly proportional to bentonite blending (up to 21%). J Mirza, 2009 studied the effect of bentonite (20-80% @20intervel) [9]. S. Ahmad, 2011 examined form 20-50 @10intervel against 2 % $MgSO_4$& 5%$Na_2SO_4$ [12]. They reported that concrete resistance is increased against sulphate by addition of bentonite around 20-30%. S K Sreenivasa, 2017 reported that 15% bentonite blended concrete shown great resistance against hydrochloric acid [28]. They also suggest that bentonite utilization results decrease in resistance against NaOH. O K Swarup, 2017 reported the bentonite-fly ash (50-50%) blended concrete shown poor resistance against hydrochloric acid & NaOH [29].

## VI. REINFORCED CEMENT CONCRETE (R.C.C.)

J. Mirza, 2009 preformed a test on R.C.C beam having a design load of around 40 kN against three-point loading system [9]. They made R.C.C beams by substitution of 20% raw bentonite, 25&40% (heated at $150^0$C for 3 hours) bentonite with OPC. They reported lower ultimate strengths were observed in bentonite blended concrete beams.

## VII. CONCLUSIONS

Plenty investigations were conducted by several authors with bentonite as supplementary material in concrete. The following conclusions were made based on the results reported the authors.

Bentonite collected for different sources obeys unlike physical and chemical properties. Increase in consistency, initial & final setting times was observed the bentonite collected from any source. Higher C S of cement mortar were noticed by using 20% of bentonite (heated at $150^0$C for 3 hours) substitution to OPC. Workability & density of fresh concrete was decreased by addition of bentonite (any type) in small amounts. There are discrepancies with in the literature with regards to strength (CS, STS &FS) of concrete.


Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The variation in strength results was observed for same quantity of bentonite blending. It was observed that source of bentonite collection effecting the strength of blended concrete, creating uncertainties on strength results reported by several authors. There is an improvement in durability of concrete was observed by bentonite addition. Bentonite can be utilized as supplementary material in concrete upon thorough investigation (physical & chemical properties).

## REFERENCES


1. G R. M. Andrew, "Global CO 2 emissions from cement production," *Earth Syst. Sci. Data*, vol. 10, pp. 195–217, 2018.
2. R. Siddique, "Utilization of industrial by-products in concrete," *Procedia Engineering*, vol. 95, no. Scescm. Elsevier B.V., pp. 335–347, 2014.
3. K. Nizar, H. Kamarudin, and M. Sobri Idris, "Geopolymer lightweight aggregate View project Electrodes for Li-ion batteries View project," 2007.
4. E. Pomakhina, D. Deneele, A. C. Gaillot, M. Paris, and G. Ouvrard, "29Si solid state NMR investigation of pozzolanic reaction occurring in lime-treated Ca-bentonite," *Cement and Concrete Research*, vol. 42, no. 4. Elsevier Ltd, pp. 626–632, 2012.
5. S. Saba, J. D. Barnichon, Y. J. Cui, A. M. Tang, and P. Delage, "Microstructure and anisotropic swelling behaviour of compacted bentonite/sand mixture," *Journal of Rock Mechanics and Geotechnical Engineering*, vol. 6, no. 2. Elsevier Ltd, pp. 126–132, 2014.
6. Indian Bureau of Mines, "Indian Minerals Yearbook 2013 (Part-III : Mineral Reviews) 52 nd Edition Bentonite (Advance release) Government of India Ministry of mines Indian bureau of mines," 2015.
7. H. H. Murray, "Chapter 6 Bentonite Applications," *Developments in Clay Science*. 2006.
8. D. Alkaya and a B. Esener, "Usability of sand-bentonite-cement mixture in the construction of unpermeable layer," vol. 6, no. 21. pp. 4492–4503, 2011.
9. J. Mirza, M. Riaz, A. Naseer, F. Rehman, A. N. Khan, and Q. Ali, "Pakistani bentonite in mortars and concrete as low cost construction material," *Applied Clay Science*, vol. 45, no. 4. Elsevier B.V., pp. 220–226, 2009.
10. S. A. Memon, R. Arsalan, S. Khan, and T. Y. Lo, "Utilization of Pakistani bentonite as partial replacement of cement in concrete," *Construction and Building Materials*, vol. 30. Elsevier Ltd, pp. 237–242, 2012.
11. S. Ahmad, S. A. Barbhuiya, and A. Elahi, "Effect of Pakistani bentonite on properties of mortar and concrete." pp. 85–92, 2011.
12. Juniad Akbar, Bashir Alam, Muhammad Ashraf, Salman Afzal, Asfandyar Ahmad, and Khan Shahzada., "Evaluating the Effect of Bentonite on Strength and Durability of High Performance Concrete," *International Journal of Advanced Structures and Geotechnical Engineering*, vol. 02, no. 01. pp. 1–5, 2013.
13. S. Afzal, K. Shahzada, M. Fahad, S. Saeed, and M. Ashraf, "Assessment of early-age autogenous shrinkage strains in concrete using bentonite clay as internal curing technique," *Construction and Building Materials*, vol. 66. Elsevier Ltd, pp. 403–409, 2014.
14. M. E. Shabab, K. Shahzada, B. Gencturk, M. Ashraf, and M. Fahad, "Synergistic effect of fly ash and bentonite as partial replacement of cement in mass concrete," *KSCE Journal of Civil Engineering*, vol. 20, no. 5. pp. 1987–1995, 2016.
15. Reddy G, V Ranga Rao, and M Achyutha Kumar Reddy, "Experimental investigation of strength parameters of cement and concrete by partial replacement of cement with Indian calcium bentonite," *Int. J. Civ. Eng. Technol.*, vol. 8, no. 1, 2017.
16. B. P. Kumar, V Ranga Rao, and M Achyutha Kumar Reddy, "Effect on strength properties of concrete by partial replacement of cement with calcium bentonite and fly ash," *Int. J. Civ. Eng. Technol.*, vol. 8, no. 4, 2017.
17. D. J. Lima-Guerra, I. Mello, R. Resende, and R. Silva, "Use of Bentonite and Organobentonite as Alternatives of Partial Substitution of Cement in Concrete Manufacturing," *International Journal of Concrete Structures and Materials*, vol. 8, no. 1. pp. 15–26, 2014.
18. R. A. Khushnood, S. A. Rizwan, S. A. Memon, J. M. Tulliani, and G. A. Ferro, "Experimental Investigation on Use of Wheat Straw Ash and Bentonite in Self-Compacting Cementitious System," *Advances in Materials Science and Engineering*, vol. 2014. 2014.
19. M. Karthikeyan, P. Raja Ramachandran, A. Nandhini, and R. Vinodha, "Application on partial substitute of cement by bentonite in concrete," *International Journal of ChemTech Research*, vol. 8, no. 11. pp. 384–388, 2015.
20. Divyana R, "An Experimental Study on Concrete Using Bentonite and Steel Slag," 2015.
21. J. M. A. Kadar and G. Dhanalakshmi, "Experimental Investigation on Concrete by Partial Replacement on Cement by Bentonite and Coarse Aggregate by Steel Slag." pp. 10302–10309, 2016.
22. J. Chamundeeswari, "Experimental study on partial replacement of cement by bentonite in paverblock," *Int. J. Eng. Trends Technol.*, vol. 3, no. 6, pp. 41–47, 2012.
23. R. Selvaraj and R. Priyanka, "Characteristics study of bentonite mortar with partial replacement of cement," *Int. J. Eng. Sci. Invent. Res. Dev.*, vol. II, p. 178, 2015.
24. M. Chandrakanth and N. S. P. C. Rao, "Experimental Studies on Concrete with Bentonite as Mineral Admixture," vol. 1, no. 2. pp. 7–10, 2016.
25. M. Aravindhraj and B. T. Sapna, "Influence of Bentonite in Strength and Durability of High Performance Concrete." pp. 3120–3124, 2016.
26. J. Mohammed, A. Kadar, and G. Dhanalakshmi, "Experimental Investigation on Concrete by Partial Replacement on Cement by Bentonite and Coarse Aggregate by Steel Slag," *Int. J. Innov. Res. Sci. Eng. Technol. (An ISO*, vol. 3297, 2007.
27. M. Chandrakanth, N. S. Poorna, C. Rao, and K. Srinivasa Rao, "Experimental Studies on Concrete with Bentonite as Mineral Admixture," 2016.
28. S. K Sreeniva, S. K. P Praneeth, K. R. M AchyuthA, and R. V Ranga, "A Study on Durability of Concrete by Partial Replacement of Cement with Bentonite A Study on Durability of Concrete by Partial Replacement of," *Int. Chem Tech Res.*, vol. 10, no. 6, pp. 898–904, 2017.
29. O. K. Swarup, P. V. R. Reddy, M. Achyutha, K. Reddy, and V. R. Rao, "A Study on Durability of Concrete by Partial Replacement of Cement with Bentonite and Fly Ash," *Int. Chemtech Res.*, vol. 10, no. 7, pp. 855–861, 2017.
30. http://www.renewable-energysources.com/ accessed on 19/09/2018.
31. Nevelli, A M., 2011, Properties of Concrete, Pearson Education Limited, 5th Edition.

## AUTHORS PROFILE

**M. Achyutha Kumar Reddy** is pursuing Ph.D. in Civil Engineering, Koneru Lakshmaiah Education Foundation (Deemed to be University), Vaddeswaram, Andhra Pradesh. He has published 12 research papers.

**V. Ranga Rao** is working as Professor, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, AP, India. He has completed Ph.D. in Structural Engineering from Andhra University in 1999. His research interests include Dykes, Check dams, Roads & Rehabilitation and Retrofitting of RC structures. He has published 28 research papers in international journals and conferences and guiding 1 number of Ph.D. scholars, guided 15 number of masters and 10 number of bachelor's dissertation work.