# A Review on Different Parameters of Pavement by Replacing Cement with Metakaolin, GGBS and Silica Fume and their Beneficial Uses

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**Abstract**

*Development is required to discover elective development strategies that will expand the adequacy of the existing spending plans, along these lines accomplishing all the more number of streets, Replacing Cement with Metakaolin; GGBS and Silica Fumes is one of the options. Cement is the core part of concrete which binds it and provides strength to the concrete. The high strength of concrete requires high blended cement, therefore to reduce its dependency on cement it is necessary to introduce some other material that can be replaced or partially replaced by cement. In this review, three materials are discussed which can reduce the dependency on cement. These materials are Metakaolin, GGBS and Silica Fumes. All the material can be partially replaced by cement and gives high strength to concrete. Mixing of Metakaolin in concrete increases its strength and the mixing of GGBS increases its strength as well as helps in reducing air pollution from the environment. Replacement of cement is beneficial for both economical and the environmental. It also states the background and deep study Metakaolin, GGBS and Silica Fumes. This review deals use Metakaolin, Silica Fumes, and ground granulated blast furnace slag (GGBS) in the formation of concrete. This review details about the properties, advances, effects in concrete. It also includes chemical composition, their properties, advantages and limitations of source materials.*

**Keywords:** *Aggregates, Concrete, Silica Fumes, Metakaolin, GGBS.*

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## Introduction

The last decade has been an era of tremendous growth for the Indian economy. Sustainability of the Indian economic growth will largely need the support of good infrastructural, road network, etc. and will influence the trajectory of growth in the coming few decades. The building, Road network not only influences economic growth but connects many of the backward and rural areas to be developed parts of the nation. The development of the agriculture sector is directly proportional to the development in infrastructure as rural connectivity is perceived as one of the major components in increasing agriculture output and earning capacity of rural populations. Despite their importance to the national economy, the road network in India is inadequate in various respects. The existing network is in adequate and it is unable to handle high traffic density in many places and it has poor riding quality. Road safety is a major concern in the present day of the world. India's rank is 2nd in traffic-related deaths. Now a day India has the 2nd largest road network in the world with 5903293 km. In this, we are studying the Rigid pavement road because in a country like India bitumen pavement road is widely used and we discuss the Concrete property and how we can enhancement the concrete property by using different types of materials. Only with the transition of hundreds of years, several civilizations are experiencing relative problems regarding their street networks. Extending the reach of road maintenance programs is needed to hold clean the current roads as well as less money is sufficient to rehabilitation or major programs. Inside a variety of countries, such as India, there's still essentially inadequate money to compete effectively with spending commitments, contributing to a steady downturn and increasingly expensive recovery figures that would be expected throughout the longer term to restore service standards. Going to upgrade infrastructure or modern bridges would only be pursued unless the income through toll booths offers a basis only for capital cost. Road engineers have also been faced with the difficulty of such a situation of collapse. Various groups as well as the World Bank have reported that perhaps the existence of better roads is indeed an integral part of this system in several countries that require a stable structure for economic quality of life-being. A much more realistic plan regarding road reconstruction must be established at this point of view of a shortage of capacity for available infrastructure to support the current crisis. Also, GGBS can be obtained from locally iron industries. The chemical properties of materials are improved to overcome these limitations. By using thermoplastic like ethylene-vinyl acetate stability of bitumen can be enhanced. Bituminous mix uses fillers as admixtures which have a great effect on performances. Fillers may be cement, sand, Metakaolin, fine sand, stone dust, etc. It fills gaps between aggregates and bitumen. There are several studies conducted for the evolution of different fillers (Cloptelet el., 2012; Underwood & Kim, 2011; Kim &Buttlar, 2010). So, it is important to study the binder morphology as well as the mechanical properties of fillers. Fillers may be crushed stone (Melotti et al., 2013), brick powder (Chen et al., 2011), glass dust (Tremblay et al., 2015), marble dust (Chandra et al., 2002) for bitumen mix. The amount and type of filler materials define the pavement's quality and durability. Most suitable filler materials are fine sand, ash, brick dust, marble dust which has sieve size less than 0.075mm (Sutradhar et al., 2015). Now a day's the waste powder as filler in BC mix has become a wide research area. Phosphate waste filler (Katamine, 2000), bag-house fines (Lin et al., 2006), ceramic waste materials (Huang et al., 2009), MSW incineration ash (Xue et al., 2009), crumb rubber (Abdel-Motaleb, 2007), waste recycled lime (Do et al., 2008) and many more have been examined as fillers. The performance of pavements can be enhanced by using recycled fillers (Eisa et al., 2018). Cement is used to increase strength in the pavement, but by adding fly ash in it reduces stripping and also increases stiffness resistivity (Likitlersuang and Chompoorat, 2016). GGBFS as filler also showed higher efficiency with cement, it reaches high compressive strength as compared to others (Soliman and Nehdi, 2014; Lekhaz et al., 2015; Pathak et al., 2014). Sub-grade soil can be stabilized by using GGBS which is an industrial waste (Bera et al, 2018). Research is expected to explore outpatient planning techniques that would improve the appropriateness of a current expenditure program, all through sections, by growing the number of roads.

## Materials and Methodology:

- **Metakaolin:** Metakaolin is a mineral that contains silica and clay is predominant, almost in half ratio, 48.3 % CaO, and 51.7% SiO2. It also contains a small amount of manganese (Mn), iron (Fe) and magnesium (Mg). The chemical formula for Metakaolin is "CaSiO3". It forms due to the weathering action or can say from the metamorphism reaction on limestone. So Metakaolin is a metamorphic rock. It is found in different colors like white, grey, pale green, pinkish, red, brown, yellow, etc. with high brightness. Metakaolin has different crystal shapes. It is not found in circular shape although it is found in the needle-like crystal structure. The length of the Metakaolin microfiber is 0.4 – 0.6 mm and dia. 25 – 150 µm and less than 25 µm will be considered as powder and more than 150 µm will be considered as fibers. Because of its shape, it can also be used as a filler and can be replaced by sand also. From different researches, it was proved that the use of Metakaolin as a replacement of cement or as filler in place of fine aggregates and sand improves the flexural strength, its compressive strength and ductility of the concrete. India is the second-largest producer of Metakaolin after China. It is profusely found in Pali (Rajasthan), Sirohi Dist., Udaipur and also found in Uttarakhand, Andhra Pradesh, and Tamil Nadu. It has similar properties to cement. Also, it has its binding properties. So it can be used as a replacement or partial replacement of cement with some ratio. It helps to reduce cracking and glaze effect. It can be used as an additive in paints and helps in improvement in the durability of the paint. It also uses plastic to increase its flexural strength. Metakaolin is used in friction products like breaks and clutches. One another use of Metakaolin is its use in the tile manufacturing industries.
- **Properties of Metakaolin:** The following properties are mentioned in below:
  - **Specific gravity:** The specific gravity of Metakaolin is in-between range of 2.87 – 3.09.
  - **Colour:** Pure Metakaolin has white in colour bug due to impurities or even small amount of impurities it may in colour cream, pinkish, red or brown. These colours will appear due to the presence of iron and the other colouring ions.
  - **Melting point:** Pure Metakaolin has a melting point of 1540º C but some amount of impurities present in the Metakaolin so practically the value will be lower. The melting point will be 1380 ºC.
  - **Acicular structure:** Metakaolin has a different structure such as acicular structure or needle-like structures which make it useful in different purposes
- **Ground granulated Blast Slag**: Being a by-product of blast furnaces, Ground granulated blast slag (GGBS) is often utilized in iron production (Li and Zhao, 2003; Suresh and Nagaraju, 2015). This material can be obtained at temperatures of almost 1500 C and is fed with a cautiously controlled mixture of iron ore, coke, and limestone (Suresh and Nagaraju, 2015). The melted slag has a content of about 40% calcium oxide (CaO) and 30-40% silicon dioxide ($SiO_2$), which is near to the chemical formation of OPC. When iron ore is reduced to iron, the residual materials create a slag that floats on top of the iron (Suresh and

Nagaraju, 2015). This slag is regularly tapped off as a molten liquid and must be quenched quickly in large volumes of water to manufacture GGBS (Sahithi and Priyanka, 2015). This quenching process utilizes the cementations properties of the slag and engenders granules comparable to coarse sand. The granulated slag is subsequently desiccated and ground to a fine powder. GGBS can replace the OPC content of concrete by 35-70% and exhibits excellent properties when finely ground and combined with other materials to form GeoPc. The glass particles of GGBS comprise Q0-type mono-silicates, which are comparable to those being applied in ordinary Portland cement clinker and dissolve upon activation by any medium (Amoudi, 1993). GGBS's glass content typically exceeds 85% of its total volume, while its specific gravity ranges from 2.7 to 2.90 (lower than that of ordinary Portland cement), and its bulk density varies between 1200 kg/m3 and 1300 kg/m3 (Ismaiel, 2014). The standard chemical composition of this material is presented in Table 1. The chemical composition of ordinary cement shows more similarities to that of GGBS than of other mineral admixtures, such as POFA concrete (Ismaiel, 2014).

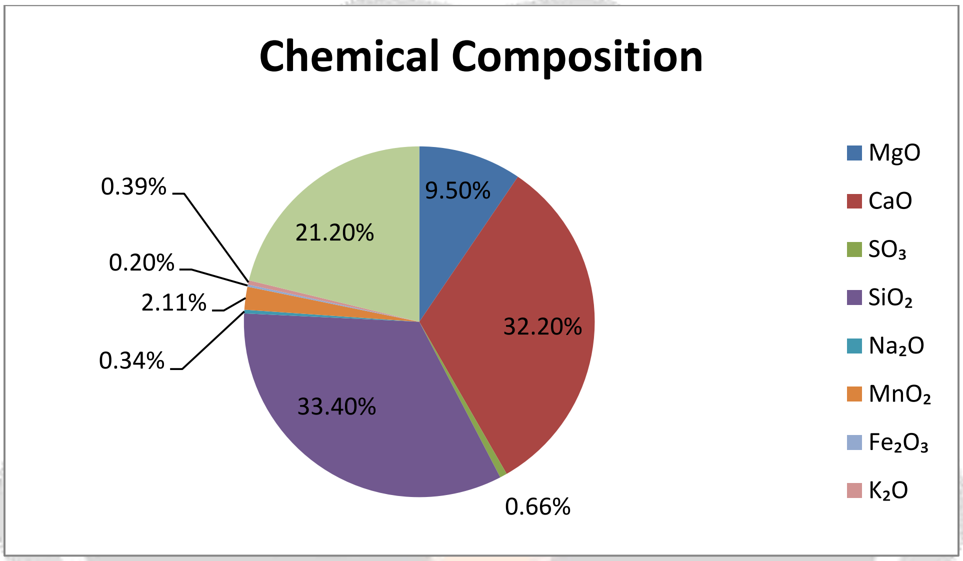


**Figure 1:** Chemical composition of GGBS

GGBS can be used for refining the pores and increasing the long term strength, sulfate, and alkali-silica reaction resistance of concrete as well as for reducing the water demand, permeability, and heat generation during the hydration process (Castel and Foster, 2015; Ismaiel, 2014; Suresh and Nagaraju, 2015). However, the addition of GGBS can influence the reaction, characteristics and PC matrix. The influence is varied based on the volume of GGBS added (5-50%). It is found that the reaction at 27 C is governed by the GGBS activation. The reaction at 27 C is contributed by precipitation and dissolution of CeSeH gel due to the alkali activation of GGBS (Li and Zhao, 2003; Sahithi and Priyanka, 2015). Moreover, in the production of GEOPC, the aluminum and silicon present in the GGBS are activated by a mixture of sodium silicate and sodium hydroxide solutions to produce the geopolymer paste that binds the aggregates (Islam et al., 2015). It may be deduced that the increased addition of GGBS can increase the ultrasonic pulse velocity, resistance to acid and compressive strength of GeoPC at all curing regimes (Sangeetha, 2015).

- **Silica Fume**: Silica Fume, also known as micro silica, is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production silica fume is an ultrafine material with spherical particles less than 1 in diameter, the average being about 0.15. This makes it approximately 100 times smaller than the average cement particle. The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 (unidentified) to 600 kg/m3. Ahmad et al carried out the study of concrete involving the use of waste paper sludge ash as a partial replacement of cement and concluded that 5% replacement of cement by waste paper sludge ash showed a 10% increase in compressive strength at 7 days and 15% increase in compressive strength at 28 days. The search for suitable local materials to manufacture pozzolana cement was therefore intensified. Most of the increase in cement demand could be met by the use of supplementary cementing materials, in order to reduce the green gas emission (Bentur, 2002). High strength concrete means good abrasion, impact and cavitations resistance. Using high strength concrete in structures today would result in economic advantages. The investigation on silica fume in high- strength concrete at a constant water binder ratio (w/b) of 0.34 (Yogendran et al) and replacement percentages of 0 to 25% with varying dosages of HRWRA. The maximum 28-day compressive strength was obtained at 15% replacement level Bhanja et al reported and directed towards developing a better understanding of the isolated contributions of silica fume concrete and determining its optimum content. a study carried out to improve the early age compressive strength of Portland slag cement (PSC) with the help of silica fume. Silica fume from three sources: one `imported, two indigenous were used in various proportions to study their effect on various properties of PSC. Faseyemi Victor Ajileye did the Investigations on Micro silica (Silica Fume) As partial cement replacement in concrete and made the conclusions that cement replacement up to 10% with silica fume leads to an increase in compressive strength, for C30 grade of concrete. From 15% there is a decrease in compressive strength for 3, 7, 14 and 28 days curing period. It was observed that the compressive strength of the C30 grade of concrete is increased from 16.15% to 29.24% and decrease from 23.98% to 20.22%. The maximum replacement level of silica fume is 10% for the C30 grade of concrete.

**Effect of aggregates:** It is well known that he variation in material characteristics also influence the rutting resistance of bituminous materials. (Archilla and Madanat, 2001) did some research work on investigating how the properties of aggregate would relate to the mixture. Bigger are the most extreme aggregate size, better is the execution regarding rutting resistance, since they more often do not give voids in minerals aggregates **(**Siddharthan et al., 2002). In India the MORTH suggests a normal air void substance on a recently cleared bituminous blend is 3% to 6%.

**Material Used:** The properties of the component materials often used to build concrete matrices are calculated according to specific IS code. Different properties of the material had been studied in order to ensure code requirements as well as to design the concrete.

- Metakaolin
- Silica Fume
- GGBFS
- Portland Cement
- Coarse Aggregates
- Fine Aggregates.

**Method of Mixing:** Replacement of cement (by weight) will be done with all these Materials. While mixing of the materials in cement use the standard procedure. Replace the calculated cement homogeneously. The replacement of the cement will be done by weight. So the replacement of GGBS, Metakaolin Silica Fume will be taken as by weight. In this research, three kinds of tests will be conducted.

- **Compressive Strength test:** The characteristic compressive strength of 150mm size cube tested at 28 days. The characteristic strength is the strength of concrete below which not more than 5% of the test result is expected to fall (IS 456-2000). The strength of concrete depends upon cement proportioning, fine and coarse aggregates, water, and admixtures. The strength of concrete is inversely proportional to water-cement ration i.e. lower the water-cement ratio higher the strength.
- **Flexural test:** This test calculates the tensile strength indirectly. It tests the strength of a beam or slab without reinforced to withstand failure in bending. The result of the flexural test on concrete beams represents as modulus of rupture. IS 516-2002 guidelines should be followed.
- **Split tensile strength test:** The split tensile strength test is determined by IS code 516-1959. The test is conducted on concrete cylinder which dimensions 150mm× 300 mm; compression load is applied to it. The load is applied until sample failure. Compressive stress produces transverse tensile stress, which is uniform throughout the vertical diameter.

**Benefits of using GGBFS and Metakaolin in concrete pavement:**

- One of the greatest benefits of using GGBFS and Silica Fume in concrete pavement is reducing the dependency on cement.
- Different study proves that using of GGBFS in concrete improves the self cleaning property of concrete.
- Using of Metakaolin in concrete increases the strength of concrete as it settles in very fine pores of the concrete and reduces cavity because of its needle-like structure.
- The Main advantage of using both silica fume and GGBFS in concrete helps in making eco-concrete or green concrete. After mixing the GGBFS in concrete it can be named as ‘photo catalytic concrete.
- Using of both Metakaolin and GGBFS in concrete increases its compressive strength Flexural strength will be increased by using Metakaolin and GGBFS in concrete .Using GGBFS in concrete can helps in reducing

$NO_2$ from the environment by photo catalysis, which is one of the most emitted pollutants emits from automobiles.

**Future scope:** The Use of Metakaolin and silica fume can also be increased in concrete because of its special shape which makes concrete more durable and strong at a low cost. As studying different researches it can be clear that green concrete can be the future of ordinary concrete.

**Conclusion:** The movement of moisture of GGBS and silica fumes mixes, probably due to the dense and strong microstructure of the interfacial aggregate/binder transition zone is probably responsible for the high resistance of GGBS mixes to attack in aggressive environments such as silage pits. The mineral composition of GGBS cement paste probably contributes to this resistance. As we have seen GGBS and Metakaolin is a good replacement to cement in some cases and serves effectively but it can‟ replace cement completely. But even though it replaces partially it gives very good results and a greener approach in construction and sustainable development which we are engineers are keen about today.

## References


- Amin, M., & Abdelsalam, B. A. (2019). "Efficiency of rice husk ash and fly ash as reactivity materials in sustainable concrete". Sustainable Environment Research, 29(1), 30.
- Amoudi, O. S. B., Rasheed uzzafar, M. M., & Al-Mana, A. I. (1993). "Prediction of long term corrosion resistance of plain and blended cement concretes". ACI Mater J, 90(6), 564-70.
- Ajay Singh and Magandeep "The Summary of Metakaolin and GGBS in Flexible Pavements: - A Critical Review from the Technical Point of View" Journal of Xidian University, ISSN No: 1001-2400.
- Ajay , Magandeep "Use of Construction or Demolition Waste in Bitumen Paving Mix:-A REVIEW" International Journal of Technical Research, Vol. 6, Issue 2, July-August 2017.
- Ajay, K., Kalyani, M., Devendra, K., & Om, P. (2012). "Properties and industrial applications of rice husk: A review". International J. of Emerging Technology and Advanced Engineering, 2, 86-90.
- Ajay, Magandeep, " Strength of Asphalt Concrete with Different Proportion of C & D Waste Using Marshall Stability Test" International Journal of Technical Research, Vol. 8, Issue 3, Nov-Dec 2017.
- Ballari M.M, Hunger M, sken G.H. & Brouwers H.J.H. (2010). "Modelling and experimental study of the $NO_2$ photo catalytic degradation employing concrete pavement with titanium dioxide". Building material building performance.
- Board, N. P. C. S. (2012). Handbook on Agro-Based Industries. Niir Project Consultancy Services.
- Castel, A., & Foster, S. J. (2015). "Bond strength between blended slag and Class F fly ash geopolymer concrete with steel reinforcement". Cement and Concrete Research, 72, 48-53.
- Chindaprasirt, P., De Silva, P., &Hanjitsuwan, S. (2014). "Effect of high-speed mixing on properties of high calcium fly ash geopolymer paste". Arabian Journal for Science and Engineering, 39(8), 6001-6007.
- Givi, A. N., Rashid, S. A., Aziz, F. N. A., &Salleh, M. A. M. (2010). "Contribution of rice husk ash to the properties of mortar and concrete: a review". Journal of American Science, 6(3), 157-165.
- He, J., Jie, Y., Zhang, J., Yu, Y., & Zhang, G. (2013). "Synthesis and characterization of red mud and rice husk ash-based geopolymer composites". Cement and Concrete Composites, 37, 108-118.
- IRC, SP 53-2002. Guidelines on the use of polymer and rubber modified bitumen in road construction.
- IS 73: 2013 "Paving bitumen-specification (Fourth Revision)". Bureau of Indian Standards, New Delhi, India.
- IS: 1203, 1978. "Methods for Testing Tar and Bituminous Materials: of Penetration". Bureau of Indian Standards, New Delhi, India.
- IS: 1205, 1978. "Methods for Testing Tar and Bituminous Materials: Determination of Softening Point". Bureau of Indian Standards, New Delhi, India.
- IS: 2386 (Part I). 1963. "Methods of test for aggregates for concrete". Bureau of Indian Standards, New Delhi, India. IS: 2386 (Part III). 1963. "Methods of test for aggregates for concrete". Bureau of Indian Standards, New Delhi, India.
- IS: 2386 (Part IV). 1963. "Methods of test for aggregates for concrete". Bureau of Indian Standards, New Delhi, India.
- Islam, A., Alengaram, U. J., Jumaat, M. Z., Bashar, I. I., &Kabir, S. A. (2015). "Engineering properties and carbon footprint of ground granulated blast-furnace slag-palm oil fuel ash-based structural geopolymer concrete". Construction and Building Materials, 101, 503-521.

- Ismaiel, S. M. E. S. (2014) “Study physic-chemical properties of blended cement containing fixe amount of silica fume, blast furnace slag, basalt and limestone, a comparative study”. Constr. Build. Mater, 72, 104-112.
- Junaid, M. T., Khennane, A., Kayali, O., Sadaoui, A., Picard, D., & Fafard, M. (2014). “Aspects of the deformational behavior of alkali-activated fly ash concrete at elevated temperatures. Cement and Concrete Research” 60, 24-29.
- Kim, Y. Y., Lee, B. J., Saraswathy, V., & Kwon, S. J. (2014). “Strength and durability performance of alkali-activated rice husk ash geopolymer mortar”. The Scientific World Journal, 2014.
- Kishanrao, M. P. (2013). “Design of geopolymer concrete. International Journal of Innovative Research in Science” Engineering and Technology, 2(5), 1841-1844.
- Li, G., & Zhao, X. (2003). “Properties of concrete incorporating fly ash and ground granulated blast-furnace slag”. Cement and Concrete Composites, 25(3), 293-299.
- Marais, H., Botha, C., Hofsink, W., Muller, J., & van Heerden, J. (2017, August). “Latest developments in crumb rubber modified bitumen for use in asphalt and seals-the South African experience”. In AAPA International Flexible Pavements Conference, 17th, 2017, Melbourne, Victoria, Australia.
- Magandeep, Ravi Kant Pareek and Varinder Singh, “Utilization of Ground Granulated Blast Furnace Slag to Improve Properties of Concrete” International Journal on Emerging Technologies 6(2): 72-79(2015), ISSN No. (Online): 2249-3255.
- MEHTA, P. K. (1992). “Rice Hush Ash-A unique supplementary cementing material”. Advances in concrete technology.
- Mehta, P. K. (2002). U.S. Patent No. 6,451,104. Washington, DC: U.S. Patent and Trademark Office.
- Mohamed Usman, M. K., & Senthil Pandian, M. (2014). “Study on Fly Ash and Rice Husk Ash Based Geopolymer Concrete with Steel Fibre”. Civil Engineering Systems and Sustainable Innovations.
- Magandeep, Ravi Kant Pareek and Varinder Singh, “Study of blast furnace slag to improve properties of concrete - A Review” International Journal of Technical Research, Vol. 4, Issue 1, Mar-Apr 2015.
- Nanda Kishore, G., & Gayathri, B. (2017). “Experimental Study on Rice Husk Ash & Fly Ash Based Geo-Polymer Concrete Using M-Sand”. MS&E, 225(1), 012273.
- Nuaklong, P., Sata, V., & Chindaprasirt, P. (2016). “Influence of recycled aggregate on fly ash geopolymer concrete properties”. Journal of Cleaner Production, 112, 2300-2307.
- Owais Ahmed Shaikh, Magandeep “Analysis for Improvement of Parking Facilities in the Central Business District of Srinagar” ISSN [ONLINE]: 2395-1052, IJSART - Volume 4 Issue 6 – JUNE 2018.
- Parveen Kumar, Magandeep and Karan Singh “Upshot of Human Hair Fibre in asphalt mix for pavement design: a review” Journal of Xidian University, ISSN No:1001-2400 VOLUME 14, ISSUE 8, 2020.
- Parveen Kumar, Magandeep and Karan Singh, “Upshot of Human Hair Fibre in asphalt mix for pavement design: a review” Journal of Xidian University ISSN No:1001-2400 volume 14, issue 8, 2020
- Raijiwala, D. B., & Patil, H. S. (2011). “Geopolymer concrete: A concrete of the next decade”. Concrete Solutions 2011, 287.
- Ravat, D., Shah, S., & Dave, S. (2017). “Utilization of Red Mud in Geopolymer Concrete-A Review”. Int. J. Adv. Eng. Res. Dev, 4, 738-741.
- Rajdeep Singh, Magandeep Bishnoi, “An experimental investigation of concrete properties M30 due to incorporation of glass fibres.” International Journal For Technological Research In Engineering, ISSN (Online): 2347 – 4718, Volume 4, Issue 10, June-2017.
- Ritu Bala, Magandeep Bishnoi, “Shear Strength Characteristics of Crushed Limestone Sandstone and Gravel ” (IJTR), Vol. 5, Issue 3, Nov-Dec 2016.
- Sahithi, K., & PRIYANKA, G. S. (2015). “The Effect of Addition of Limestone powder and Granulated Blast Slag in Concrete”. Int. J. Comput. Eng. Res. Trends, 2.
- Sangeetha, B. N. (2015). “Effect of Rice Husk Ash and GGBS on the performance of concrete”. IJERT, 4, 491-495.
- Sanjayan, J. G., Nazari, A., & Pouraliakbar, H. (2015). “FEA modeling of fracture toughness of steel fiber-reinforced geopolymer composites”. Materials & Design, 76, 215-222.
- Saravanan, M. M., &Sivaraja, M. (2016). “Mechanical behavior of concrete modified by replacement of cement by rice husk ash”. Brazilian Archives of Biology and Technology, 59(SPE2).
- Shoubi, M. V., Barough, A. S., & Amirsoleimani, O. (2013). “Assessment of the roles of various cement replacements in achieving sustainable and high-performance concrete”. International Journal of Advances in Engineering & Technology, 6(1), 68.

- Singh, B., Ishwarya, G., Gupta, M., & Bhattacharyya, S. K. (2015). "Geopolymer concrete: A review of some recent developments". Construction and building materials, 85, 78-90.
- Suresh, D., &Nagaraju, K. (2015). "Ground granulated blast slag (GGBS) in concrete–a review". IOSR Journal of mechanical and civil engineering, 12(4), 76-82
- Pardeep Singh, Magandeep "A Result Paper on Experimental Study of Demolished Concrete use in Rigid Pavement Construction" (IJTSRD), e-ISSN: 2456 – 6470, Volume: 3 | Issue: 4 | May-Jun 2019.
- Rajdeep Singh, Magandeep "An experimental investigation of concrete properties m30 due to incorporation of glass fibres." International Journal For Technological Research In Engineering, ISSN (Online): 2347 – 4718, Volume 4, Issue 10, June-2017.
- Ravi Prakash Sharma, Magandeep "Utilization of marble dust for stabilisation of clayey soil." International Journal of Science Technology & Management, ISSN: 2321-774X, Volume 6, Issue 2, July 2018.
- Sachin and Magandeep "Innovative Uses of Metakaolin and Recycled Polyethylene Terephthalate in Flexible Pavements: A Review" Journal of Xidian University, ISSN No: 1001-2400.
- Sunil Kumar, Magandeep Bishnoi "An Experimental Study of Bituminous Mix by Using Different Types of Fibre" International Journal of Science Technology & Management, ISSN: 2321-774X, Volume 7, Issue 2, and July 2019.
- Sorathia Jay, Shah Dr. Siddharth & Kacha Mr. Smit (2017). "Effect of addition of nano "Titanium dioxide" ($TiO_2$) on compressive strength of cementations concrete". Kalpa Publications in Civil Engineering

.

- Vikram , Magandeep Bishnoi, "Partial Replacement of Cement With Nanosilica To Micro Structural Investigation For Strength Properties Of Cement Mortar" (IJTR) Vol. 5, Issue 1, Mar-Apr 2016.