

Utilization of Granite Slurry Waste in Concrete: A Review

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Abstract

Objective: Huge quantity of granite production leads to the collection of enormous quantity of slurry. Random disposal of this generated waste degrades the environment in numerous ways. Utilization of this waste may solve the problem of waste generation and also the problem of scarcity of natural resources. **Methods/Analysis:** Granite slurry waste does not contain silt or organic impurities. Also, the use of this waste in place of cement will reduce energy demand, CO₂ emission and consumption of natural resources. Sufficient literature is available and it indicates that this waste can be used in place of Fine Aggregate (F.A.) or cement. In this paper salient available experimental studies using the granite slurry waste have been reviewed. **Findings:** It is shown that the granite slurry waste reduces the workability whereas compressive strength of granite concrete is improved when fine aggregate or cement is partially replaced. It has been also shown that the modified concrete performed well when level of F.A. by granite slurry waste is up to 15%. **Conclusion/Application:** Utilization of this waste will reduce the cost of concrete; reduce environmental pollution, consumption of natural resources and energy demand.

Keywords: Concrete Properties, Durability, Environmental Benefits, Granite Waste, Modulus of Elasticity, Water Permeability

1. Introduction

Concrete is generally used artificial construction material because of its economy and easy to fabrication. In the recent years, India has set out upon the infrastructure development with upgrade pace. Demand of natural river sand (F.A.) and cement is therefore rising up enormously. This escalating demand of natural sand (Fine Aggregate) and cement is creating scarcity of the natural fine aggregates and cement¹⁻³ and affecting the growth of construction industries adversely also. Rapid infrastructure development has therefore generated necessity for the sustainability of concrete and its productiveness. Innovation in advanced construction materials is highly desired for this sustainable development.

A number of developing countries have faced trouble in the delivery of natural river sand (F.A.) in order to meet

the increasing needs of infrastructural growth in current years. In many parts of India also, F.A. has excessive silt resulting in poor gradation. Replacement of natural sand is thus urgently required, so that consistent good quality of F.A. may be obtained to fulfil the demand of construction industry and simultaneously depleting resource of natural sand is protected.

Approximately five percent of CO₂ emissions worldwide are due to the cement industry⁴. Cement production is increasing annually due to more infrastructure development and it will be on increasing trend. Production of cement in India was around 900 million tonne in the year 2006 and has grown enormously up to 1300 million tonne till year 2015 and it is anticipated that the demand would reach 1950 million tonne in year 2030⁵. This increased demand of cement will further increase CO₂ emission and the increased CO₂ emission will pollute the environment.

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The cement industry is therefore required to reorganise itself in an environment friendly industry which requires less use of resources and carbon dioxide (CO₂) emissions at all phases during the construction.

Huge quantity of granite production leads to the assembly of enormous quantity of granite slurry annually. This generated granite slurry is a waste and it degrades the environment in numerous ways. Disposal of this waste is difficult and will induce many issues like land degradation, visual effect, flooding of water, air pollution. In addition, the porosity of aquifer zones and contaminating the underground water will occur if the waste is deliberately being dumped on the riverbeds⁶⁻⁸. Random disposal of the granite fines would also lead to health hazards like respiratory and allergy problems to the people dwelling in the areas.

Waste management problem is of critical concern in which waste materials are being used to produce new products in such a way that natural resources are saved. Within cement industry, industrial wastes for instance rice husk ash, red mud, blast-furnace slag etc have been used for long period in huge quantity as a raw material and admixture. Problem of scarcity of natural resources will be solved by the consumption of these varied wastes from different industries as a raw material for concrete.

Sufficient literature is available for granite slurry waste and shows that this waste has pozzolanic as well as cementitious property which can be utilized in place of cement. It has been also shown that granite slurry waste is very resourceful in improvising the concrete's cohesiveness due to its high fineness. Experimental studies available for utilization of granite slurry waste in several industrial applications such as cement, concrete, mortar, ceramics, composite materials demonstrate⁹⁻¹¹ that inclusion of this industrial waste enhances the properties i.e. physical and mechanical of these applications.

Granite slurry waste also does not consist of silt and organic impurities and may be created to fulfil desired gradation and fineness as per need and hence, it can also be used as an alternative material for natural sand (F.A). Granite slurry waste therefore will furnish a reliable quality source for fine aggregates and will preserve the depleting source of natural sand^{12,13}.

In this paper, available experimental studies using the granite slurry waste has been reviewed and the effective utilization of this material in place of F.A. and cement will be presented. In these studies, properties of granite slurry concrete (fresh and hardened concrete proper-

ties), cost and environmental benefits has been discussed. Concluding remarks of the critical review has been reported at the end.

2. Properties of Granite Slurry Concrete

Experimental studies are available in the literature for the efficient use of granite slurry waste. In these studies, utilization of waste granite slurry was reported as a varied replacement level of F.A. and cement. Further, it has been shown that utilization of granite slurry waste modifies the fresh (workability) and hardened concrete properties. In hardened concrete, the effect has been generally considered for mechanical properties (compressive strength, split tensile, etc.) and the durability properties (water permeability, rapid chloride penetration, etc). Critical review of the available literature thus has been discussed on fresh concrete properties (workability), mechanical properties and durability properties.

2.1 Fresh Concrete Properties

2.1.1 Workability

The effect of granite slurry waste as replacement to fine aggregates (ranging from 5% to 50%) in concrete production was carried out¹⁴. It has been shown that at 0.6 water cement ratio workability of modified concrete at varied replacement level was reduced with respect to control mix (0% replacement level).

Workability on granite slurry waste was studied by utilizing granite slurry waste in varied percentage ranging from 5% to 25%¹⁵. Modified concrete was observed through slump test, it was seen that workability reduces with the increase in varied level of granite slurry waste. It was also observed that poor workability was found when the replacement level was more than 20%.

Particle shape and surface texture affects the workability of the concrete. Compared to the F.A., the granite slurry waste has rough and angular geometry and also greater than 90% particle size are much less than 50 micron. The probable factor that density of the granite slurry waste contributed in reduction of paste volume furthermore this decrement in volume reduces the cohesiveness. These factors reduce the workability property of the granite slurry concrete.

2.2 Mechanical Properties

2.2.1 Compressive Strength

High performance concrete prepared with granite slurry waste in place of F.A. was examined¹⁶ for varied percentage 25% to 100% of granite slurry waste. The effect on compressive strength was observed at water cement (w/c) ratio of 0.40 and at different time interval of curing ranging from 1 day to 90 days. Variation of compressive strength with varied curing days of concrete mixes with different replacement level of granite slurry, have been shown in Figure 1. It can be observed that compressive strength of modified concrete (for all varied level) was closer to that of concrete mix (0% replacement level). It was also shown that maximum compressive strength was achieved in a sample, which contains 25% granite slurry waste at ages of curing (ranging from 1 to 90 days). Maximum compressive strength was observed as about 37MPa (28 days) for replacement level of 25% whereas compressive strength of control mix at the same water cement ratio was 35 MPa. This improvement in compressive strength was because granite slurry is having pozzolanic as well as cementitious property.

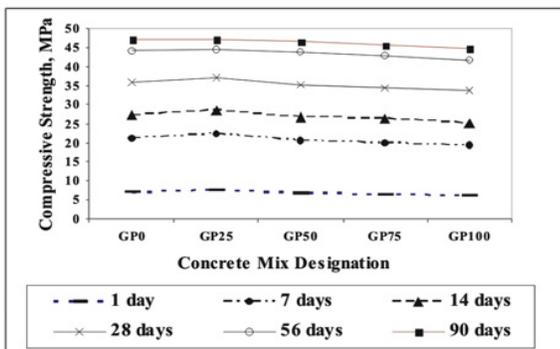


Figure 1. Variation of compressive strength with replacement levels of granite slurry waste¹⁶.

Suitability of granite slurry waste to substitute fine aggregate in production of concrete was conducted¹⁷ for the application in a rigid pavement. In this study, varied percentage 10% to 100% of granite slurry waste has used. It was reported that with the increase in granite slurry waste compressive strength also increases. In this study, maximum compressive strength was observed as 40.70N/mm² (28 days), when F.A. were replaced with 20% of granite slurry waste.

Study was executed to observe the behavior of M20 grade concrete with the use of granite slurry waste in place of F.A.¹⁴. The concrete mix was prepared with five different replacement levels 5% to 50% and at 0.6 water-cement ratio. It was shown that at replacement level of 35%, compressive strength has increased by 22% with respect to the control concrete mix (0% replacement level).

Effect on compressive strength of M60 grade concrete was also studied¹⁸ with replacement of granite slurry waste as a fine aggregates ranging from 25% to 100%. Considerable increase has been viewed compared with control concrete sample in the concrete mix with 25% granite powder. It may be noted that in this study mineral admixtures (slag 10%, silica fume 7.5%, fly ash 10 %,) and chemical admixtures (1%) were also used and study has been done for water cement ratio 0.25 to 0.35.

Different test were performed to determine the probability of using granite slurry waste in place of F.A.¹⁹. Concrete grade of M20, M30 and M40 were prepared with varied granite slurry waste of 5% to 25%. The effect on compressive strength using 0.4 water cement ratio (0.5% super plasticizer) was observed at 28 days of curing. When F.A. was replaced with 15% granite slurry waste, maximum compressive strength was observed as 32.20N/mm², 35.47N/mm² and 53.33N/mm² for different grade of concrete i.e., M20, M30 and M40 respectively.

Appropriateness of granite slurry waste as an alternate material for F.A. in making of concrete was examined¹⁵ for mixes prepared by replacing F.A. partially with granite slurry waste at varied percentages 5% to 25%. The effect on compressive strength at 0.40 w/c ratio was observed at varied days of curing (7, 28 and 90). The compressive strength of the modified concrete was increased up to 15% of replacement level with increase in age of curing.

It can be observed from the above results of available studies that increase in compressive strength was observed when the level of F.A. was varying from 15% to 25% for water cement ratio changing from 0.25 to 0.40. It can be safely assumed from the above discussion that increase in compressive strength will occur when the replacement level is up to 15%.

In the above discussed studies, fine aggregate was replaced by granite slurry. In the literature studies are also available for the replacement of cement by this waste. The properties of M30 control mix (0% replacement level) and modified concrete with granite slurry waste with partial replacement of cement²⁰ at varied percentage ranging

from 2.5% to 20% was compared. This comparison of strength was examined at 0.45 w/c ratio with 0.40 super plasticizer for varied days of curing (3, 7 and 28 days). It was shown that there was no reduction in compressive strength when replacement was 5% and 7.5 % of cement but progressive reduction in strength was noticed for the varied levels of 10% and above.

Suitability of granite slurry waste to replace cement in concrete production was carried out²¹ by using granite slurry waste at varied percentage of 5% to 15%. Effect on compressive strength at 0.45 w/c ratio was observed at 7, 14, 28 and 56 days of curing. Observed strength with different replacement level of granite slurry has been shown in Figure 2 for different curing days. It can be seen that if granite slurry waste content is higher than 5% of cement replacement it has adverse effect on the strength. The enhancement in concrete compressive strength at 5.0% granite slurry is due to the microstructure improvement caused by filling effect of high fineness of granite slurry. The reduction in strength is seen when replacement level is 7.5% or more. This reduction in strength is due to reduced cement content as cement is partially replaced by granite slurry waste.

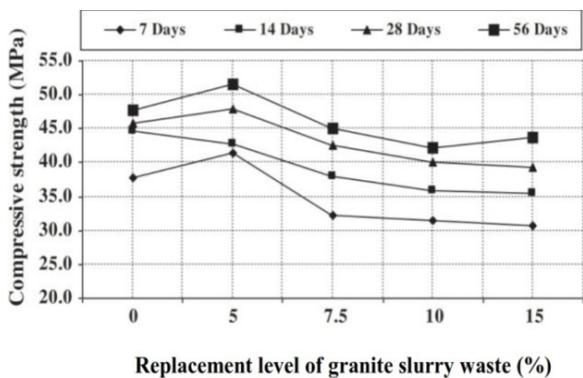


Figure 2. Compressive strength of granite slurry concrete with cement replacement²¹.

2.2.2 Split Tensile Strength

Split strength of modified concrete was examined when it was produced with granite slurry waste in place of F.A. ranging from 25% to 100%¹⁶. The split tensile strength at 0.40 w/c ratio was observed at 1, 28 and 90 days of curing and has been shown in Figure 3. It can be recognized that the tensile strength of the granite slurry concrete (for varied level) was closer to that of concrete mix (0% replacement level). It is shown in Figure 3 that the maximum tensile strength was achieved in a sample, which

contains 25% granite powder at varied ages of curing. Decrease in the split tensile strength after 25% of replacement level is due to poor inter locking between the cement paste and aggregate resulting from increased demand in cement paste volume because of increase of surface area.

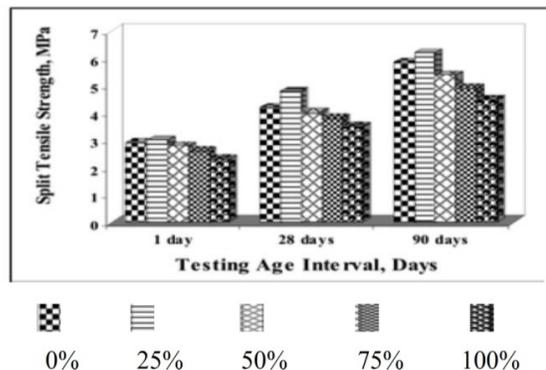


Figure 3. Variation of split tensile strength with days of curing¹⁶.

Tensile strength behavior of M20 grade of concrete by utilizing granite slurry waste in place of F.A. was observed¹⁴ for concrete utilizing the slurry waste in five different replacement levels 5% to 50%. It was shown that split tensile strength remains same for the control mix (0% replacement level) and modified concrete for replacement level of 25% and 35%. An increase of 2.4% in the strength was seen for replacement of 5% where as reduction of strength was noticed for 15% and 50% level of replacement.

Table 1. Comparison of split tensile strength of control mix and granite slurry mix¹⁸.

Water cement ratio	Replacement level of granite %	Split tensile strength (MPa)			
		Days of curing			
		1 day	7 day	28 day	90 day
0.25	0	2.90	3.80	4.68	5.00
	25	3.45	4.62	5.55	5.88
0.30	0	2.46	3.56	4.25	4.38
	25	2.95	4.35	5.16	5.25
0.35	0	2.27	3.28	3.88	4.05
	25	2.70	4.00	4.64	4.82

The split tensile strength of M60 grade concrete was also studied¹⁸ using granite slurry waste at varied replacement level ranging from 25% to 100%. The specimens were tested at varied days of curing with water cement

ratio of 0.25 to 0.35 and it was seen that maximum tensile strength was achieved at 25% replacement level. Comparison of split tensile strength of control mix (0% replacement level) and the modified concrete at 25% replacement level is shown in Table 1. It is shown that the tensile strength of the modified concrete at w/c ratio of 0.30 for 28 days has increased to about 5MPa from 4MPa for control mix. The increase in strength was found as a result of filling of unfilled micro-voids of control mix concrete by granite slurry waste.

Possibility of using granite slurry waste in place of F.A. were examined on concrete grade of M20, M30 and M40 by measuring the split tensile strength¹⁹. Varied percentages of granite slurry waste 5% to 25% were used and split strength obtained has been shown in Table 2. It is shown that maximum tensile strength was observed when F.A. was replaced with 15% granite slurry waste. It could be further shown that tensile strength for the M30 granite concrete sample increases to 3.4MPa from 2.6 MPa control sample (0% replacement level) at 28 days of curing.

Tensile strength behavior of granite concrete was observed for varied replacement of cement by granite slurry waste at 0.45 w/c ratio²¹. Results obtained for 7 to 56 days of curing have been shown in Figure 4. It is shown that the maximum tensile strength was obtained at 5% replacement of granite slurry waste for cement.

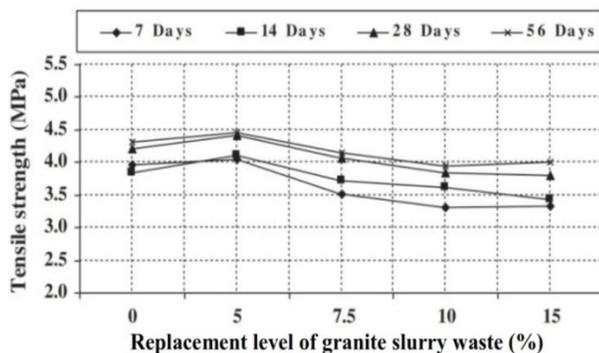


Figure 4. Tensile strength of granite slurry concrete at varied days of curing²¹.

Suitability of granite slurry waste to replace cement in concrete production was analyzed by conducting split tensile strength test²⁰. Properties of M30 control mix (0% replacement level) and granite concrete with different replacement levels at 0.45 water cement ratio with 0.4% super plasticizer for varied days of curing (3, 7 and 28 days) was observed in this study. At 5% replacement of

granite slurry waste for 28 days of curing, the maximum tensile strength observed was more than that of control sample.

Table 2. Comparison of split tensile strength for varied grade of concrete¹⁹.

S.No.	Replacement level of granite %	Split tensile strength (Mpa) at 28 days		
		M20	M30	M40
1	0	2.05	2.62	3.39
2	5	2.14	2.71	2.26
3	10	2.44	2.99	2.83
4	15	2.95	3.39	3.51
5	20	1.40	1.98	3.32
6	25	1.27	1.84	3.04

2.2.3 Flexural Strength

The suitability of granite slurry waste as fine aggregate was evaluated for concrete pavement by using varied percentage 25% to 100% of granite slurry waste¹⁷. It was revealed that flexural strength value increased with the enhancement in replacement level up to 20% and flexural strength of modified concrete at this replacement level was observed as 2.30N/mm² (28 days) whereas strength of the control concrete sample (0% replacement level) was approx 1.75 N/mm².

Flexural strength of M60 grade concrete with granite slurry waste as a replacement of F.A. ranging from 25% to 100% was also observed¹⁸. It is shown that the maximum flexural strength was achieved at 25% replacement level at varied days curing (1, 7, 28 and 90). Results obtained at this replacement level are shown in Table 3. It is also noticed that strength of granite concrete increases with curing days whereas reduction with the enhancement in w/c ratios.

Table 3. Flexural strength development compared with control mix at varied days curing¹⁸.

Water cement ratio	Replacement of granite slurry waste %	Flexural strength development (MPa)			
		Days of curing			
		1 day	7 day	28 day	90 day
0.25	25	19.88	16.78	14.80	16.29
0.30	25	17.71	16.88	13.27	14.72
0.35	25	19.88	19.20	12.50	17.48

Behavior of flexural strength of M20 grade of granite slurry concrete at five different replacement levels was studied on specimens of 100mm x100mm x500mm prepared with and without granite slurry waste¹⁴. Flexural strength obtained has been shown in Figure 5 and it was shown that the maximum flexural strength is obtained at 5% replacement level. The flexural strength at this replacement level was about 4.9MPa whereas the corresponding strength for the control specimen (0% replacement level) was about 4.6 MPa. It can be further observed from Figure 5 that there is no much change in flexural strength for all replacement levels.

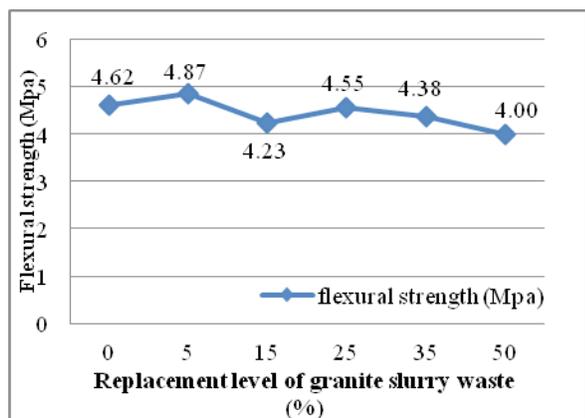


Figure 5. Flexural strength of granite slurry waste concrete at varied days of curing¹⁴.

It can be observed from the above results of split strength and flexural strength studies that increase in the strength (flexural and split) was recognized when the replacement level of F.A. was varying from 15% to 25% for water cement ratio changing from 0.25 to 0.50. It can be safely assumed from the above discussion that increase in both the strength i.e., (flexural and split) will occur when the replacement level is up to 15%.

Flexural strength of grade M30 control mix and granite slurry concrete with different replacement levels was compared at 0.45 water cement ratio with 0.4% super plasticizer for varied days of curing (7 and 28 days)²⁰. The result obtained is shown in Figure 6 and it is shown that that flexural strength for all days of curing increases when replacement level is 7.5%.

2.2.4 Modulus of Elasticity

The Modulus of Elasticity (MoE) of granite slurry concrete at different levels ranging from 25% to 100% was determined at varied days of curing (7, 28 and 90) for concrete

at 0.40 w/c ratio¹⁶. The result of this study showed that modulus of elasticity was the maximum when replacement level was 25% for 90 days of curing.

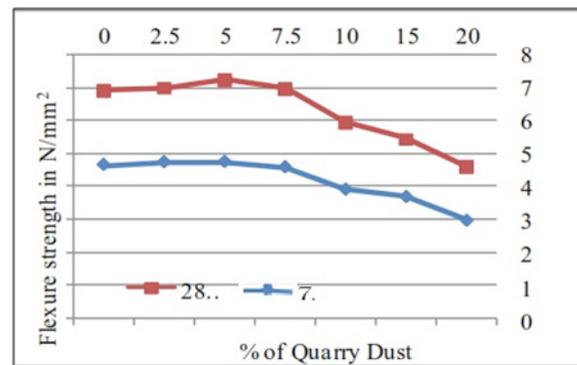


Figure 6. Flexural strength of granite concrete using granite slurry waste to replace cement²⁰.

MoE of modified concrete was determined for varied percentage ranging from 25% to 100% on at the age of 7, 28 and 90 days¹⁸. It was concluded in this study that maximum modulus of elasticity was observed at 25% replacement level. Comparison of MoE of modified concrete at 25% replacement has been shown in Table 4. It is shown that the MoE of granite slurry concrete increased as curing days increases, whereas decreases when the w/c ratio increases.

Table 4. Comparison of granite slurry concrete at 25% replacement level with control mix¹⁸.

Water cement ratio	Replacement level of granite %	Modulus of elasticity (MPa)		
		Days of curing		
		7 day	28 day	90 day
0.25	0	41.42	41.84	42.62
	25	44.50	44.92	46.30
0.30	0	38.12	38.62	40.45
	25	41.25	41.56	42.80
0.35	0	35.16	35.50	38.42
	25	39.12	39.32	42.20

2.3 Durability Properties

For effective use of granite slurry waste in the modified concrete, it is necessary that modified concrete should be durable. Water Permeability, Rapid Chlorine Penetration and Sulphate Resistance tests are generally performed to demonstrate durability of any type of concrete.

2.3.1 Water Permeability

Water permeability test on granite slurry concrete at different replacement levels ranging from 25% to 100% was performed on concrete specimens of size 100mm × 500mm × 500mm¹⁶. The results obtained are shown in Figure 7 and it can be seen that water permeability of modified concrete up to replacement level of 50% (90 days of curing) is lesser than the value obtained for the control sample (0% replacement level).

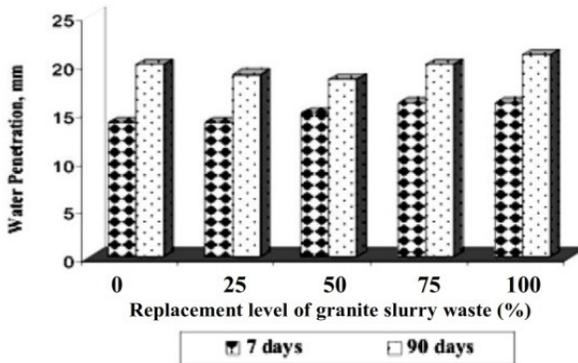


Figure 7. Variation of water penetration at varied replacement level¹⁶.

Water permeability of granite slurry concrete to demonstrate the appropriateness of granite slurry waste as an alternate material for F.A., in production of concrete was examined¹⁵. It was examined that concrete having low percentage of granite slurry waste showed low permeability. Permeability coefficient value of granite concrete having replacement level more than 20% is more than the maximum value recommended by ACI (15×10^{-3} m/s). Higher permeability coefficient is due to increase in Specific Surface Area (S.S.A.) of granite slurry waste as compared to F.A.

2.3.2 Rapid Chloride Penetration

Rapid Chloride ion Penetration Test (RCPT) was performed on granite slurry concrete at different replacement levels¹⁵. It was shown that the chloride ion permeability of prepared concrete and penetration rate was directly proportional to the replacement level. Chloride penetration values of modified concrete up to 15% replacement level were almost equivalent to that of control sample (0% replacement level). Rapid chloride penetration value after 20% replacement increases significantly. Higher replacement level of granite slurry waste resulted into high porous micro-structure and discontinuous pore system

which is responsible for the increased in rapid chloride penetration value.

2.3.3 Sulphate Resistance

Sulphate resistance test on modified concrete was performed using varied granite slurry waste percentages 5% to 25%¹⁵. In this study, compressive strength was measured after 180 and 365 days exposure in sulphate solution and the results obtained were compared with those obtained at 28 day curing (Figure 8). It is shown that the modified concrete incorporating granite slurry waste (at replacement level 25%) showed considerable fall in compressive strength with respect to concrete control mix (0% replacement level). This significant loss was resulted from deterioration of concrete, as a result of occurrence of kerosene or diesel remains in the granite slurry waste. Kerosene/diesel is generally used in sawing and polishing of granite finished product.

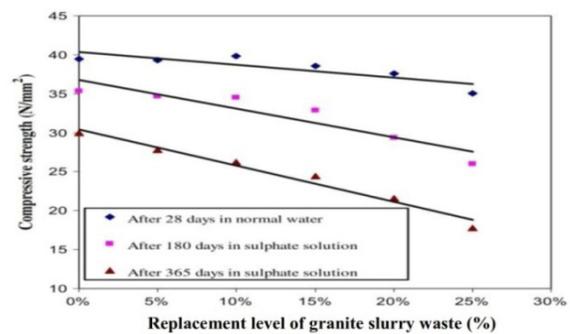


Figure 8. Loss of compressive strength in NaSO_4 and MgSO_4 solution with granite slurry waste¹⁵.

3. Cost and Environmental Benefits

The cost of concrete depends on the cost of the ingredient materials. It can be viewed from the current business scenario that cement and sand prices are increasing very fast every year due to escalating demand of cement and natural sand. It has been already reported that rising up of demand for cement and natural river sand is due to rapid infrastructure development. Granite slurry is waste material and therefore it is easily available at low cost. The utilization of this waste in place of cement will reduce the cost of concrete significantly²² because cement is most costly ingredients. The utilization of granite slurry waste will also solve the problem of energy as production of cement requires very high energy demand.

Replacement of fine aggregate with granite slurry waste will also reduce the cost of concrete. It will be also used as an alternative material because good quality natural sand is not available. Granite slurry waste has other distinct advantage that it does not consist of silt or organic impurities and may be created to fulfil desired gradation and fineness as per necessity.

Efficient use of granite slurry waste minimized the environmental pollution as the utilization of granite slurry in construction applications will reduce the effects of granite disposal on land, vegetation and ground water. The use of granite slurry waste as replacement of cement will also significantly reduce CO₂ emission because cement production is responsible for large CO₂ emissions. This reduction in CO₂ emission will reduce environmental pollution.

Rapid infrastructure development has generated necessity for the sustainability of concrete, which involves reducing natural resource consumption. Efficient use of granite slurry waste as replacement of cement will reduce the consumption of natural resources for the production of cement and these natural sources will be available for longer period. Replacement of granite slurry waste for natural sand will also furnish a reliable quality source for F.A., and will preserve the depleting source of natural sand. The use of granite slurry waste for varied replacement of cement or natural sand (F.A.) will therefore produce more sustainable concrete.

Utilization of granite slurry waste will thus contribute to the benefit and wellbeing of mankind as it will reduce environmental pollution, reduce utilization of natural resources and such system will assist in promoting the eco friendly development of various cement and concrete industry.

4. Concluding Remarks

Utilization of granite slurry waste as varied replacement of F.A. and cement in concrete has been reviewed in this paper. It has been shown that granite slurry concrete has mix behaviour depending upon the replacement level (as fine aggregates or cement). This mix behaviour of modified concrete can be summarized as below:

- Replacement of fine aggregates by granite slurry waste produces cohesive mix and reduces the workability of granite slurry concrete. Poor workability was found when the replacement level was more than 20%.

- The compressive strength of granite concrete was modified as a result of inclusion of granite slurry waste depending upon the percentage replacement (fine aggregates). It can be seen from the results of available studies that increase in strength was observed when the replacement of F.A. by granite slurry waste was upto 15%.
- Similarly, the variation in the compressive strength was observed when binding material cement is partially substitute by granite slurry waste. It can be seen from the results of available studies that increase in compressive strength was viewed when the replacement of cement by granite slurry waste was up to 5%.
- Inclusion of granite slurry waste changes the strength (split and flexural) of granite slurry concrete depending upon the replacement level of fine aggregates by granite slurry waste. From the available studies, it was discovered that increase in split tensile strength and flexural strength was examined when F.A. were partially replace by granite slurry waste up to 15%.
- Similarly, split strength and flexural strength of modified concrete was changed when cement is partially substitute by granite slurry waste. From the available studies, it was noticed that the maximum split strength was found when the replacement was 5% whereas maximum flexural strength was found at replacement level of 7.5%.
- Concrete modified with the granite slurry waste changes the MoE of granite concrete which also depends upon the replacement level of F.A., by granite slurry waste. It was observed from the available studies that the peak value of MoE was found when the replacement level was 25%.
- Water permeability, Rapid Chlorine Penetration and Sulphate resistance tests were performed on modified concrete to demonstrate the durability of this type of concrete. It can be concluded from the results of these tests that this modified concrete will perform well up to replacement level of 15% fine aggregate by granite slurry waste.
- Granite slurry is waste material and therefore it is easily available at low cost. The utilization of this waste as varied replacement of F.A., and cement will reduce the cost of concrete.

Rapid infrastructure development has generated necessity for the sustainability of concrete. Utilization of granite

slurry waste will contribute to the benefit and affluence of mankind as it will reduce environmental pollution, reduce utilization of natural resources and energy demand and this type of concrete will be more sustainable.

5. Acknowledgement

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6. References

- Almeida N, Branco F, Santos JR. Recycling of stone slurry in industrial activities: Application to concrete mixtures. *Building and Environment*. 2007 Feb; 42(2):810–9. <https://doi.org/10.1016/j.buildenv.2005.09.018>
- Hudson BP. Manufactured sand for concrete: Talks of the many properties that good manufactured sand can offer to enhance the performance of concrete. *Indian Concrete Journal*. 1997; 71:237–41.
- Safiuddin M, Raman SN, Zain MF. Utilization of quarry waste fine aggregate in concrete mixtures. *Journal of Applied Sciences Research*. 2007; 3(3):202–8.
- World Business Council for Sustainable Development (WBCSD)/International Energy Agency (IEA). *Cement Technology Roadmap 2009- Carbon emissions reductions up to 2050*. 2009. Available from: www.iea.org/papers/2009/Cement_Roadmap.pdf
- World Business Council for Sustainable Development (WBCSD)/International Energy Agency (IEA). *Cement roadmap targets; 2009b*. Available from: www.iea.org/papers/2009/Cement_Roadmap_targets_viewing_Pdf
- Rego G, Martínez C, Quero A, Blanco TP, Borquea JM. The effects of dust inhalation in slate industry workers. *Medicina Clinica*. 2001 Mar; 116(8):290–1. [https://doi.org/10.1016/S0025-7753\(01\)71802-7](https://doi.org/10.1016/S0025-7753(01)71802-7)
- Barbosa MS, Carneiro AP, Maciel JG, Moronte EA, La Rocca PD, Santos ARM. Silicosis among quartzite production workers of São Thomé das Letras-Minas Gerais region: Initial data indicate serious public health issue. *Revista Brasileira de Saúde Ocupacional*. 2011 Jun; 36(123):177–84. <https://doi.org/10.1590/S0303-76572011000100018>
- Menezes RR, Neves GA, Ferreira HC, Santana LNL. Recycling of mine wastes as ceramic raw materials: An alternative to avoid environmental contamination. INTECH Open Access Publisher; 2012.
- Pappu A, Saxena M, Asolekar SR. Solid wastes generation in India and their recycling potential in building materials. *Building and Environment*. 2007 Jun; 42(6):2311–20. <https://doi.org/10.1016/j.buildenv.2006.04.015>
- Ribeiroa SV, Holanda JNF. Soil-cement bricks incorporated with granite cutting sludge. *IJESIT*. 2014 Mar; 3(2).
- Ramos T, Matos AM, Schmidt B, Rio J, Sousa-Coutinho J. Granitic quarry sludge waste in mortar: Effect on strength and durability. *Construction and Building Materials*. 2013 Oct; 47:1001–9. <https://doi.org/10.1016/j.conbuildmat.2013.05.098>
- Mármol I, Ballester P, Cerro S, Monrós G, Morales J, Sánchez L. Use of granite sludge wastes for the production of coloured cement-based mortars. *Cement and Concrete Composites*. 2010 Sep; 32(8):617–22. <https://doi.org/10.1016/j.cemconcomp.2010.06.003>
- Binici H, Shah T, Aksogan O, Kaplan H. Durability of concrete made with granite and marble as recycle aggregates. *Journal of Materials Processing Technology*. 2008 Nov; 208(1):299–308. <https://doi.org/10.1016/j.jmatprotec.2007.12.120>
- Divakar Y, Manjunath S, Aswath MU. Experimental investigation on behaviour of concrete with the use of granite fines. *International Journal of Advanced Engineering Research and Studies*. 2012; 1(4):84–7.
- Vijayalakshmi M, Sekar AS. Strength and durability properties of concrete made with granite industry waste. *Construction and Building Materials*. 2013 Sep; 46:1–7. <https://doi.org/10.1016/j.conbuildmat.2013.04.018>
- Williams CK, Partheeban P, Kala TF. Mechanical properties of high performance concrete incorporating granite powder as fine aggregate. *India International Journal on Design and Manufacturing Technologies*. 2008 Jul; 2(1):67–73. <https://doi.org/10.18000/ijodam.70029>
- Manasseh JO. Use of crushed granite fine as replacement to river sand in concrete production. *Leonardo electronics journal of practice and technologies*. 2010 Jul; (17):85–96.
- Kala DT. Effect of granite strength powder on properties of concrete. *International Journal of Engineering and Science*. 2013 May; 2(12):36–50.
- Arulraj GP, Adin A, Kannan TS. Granite powder concrete. *IRACST. Engineering Science and Technology: An International Journal (ESTIJ)*. 2013; 3(1):193.
- Soman K, Sasi MD, Abubaker KA. Strength Properties of Concrete with Partial Replacement of Cement by Granite Quarry Dust. *International Journal of Engineering Research and Technology* 2014 Sep; 3(9).
- Elmoaty AE. Mechanical properties and corrosion resistance of concrete modified with granite dust. *Construction and Building Materials*. 2013 Oct; 47:743–52. <https://doi.org/10.1016/j.conbuildmat.2013.05.054>
- Srinivasa CH. Optimization of granite powder used as partial replacement to cement in the design of ready mix concrete of M20 grade using IS10262: 2009. *International Journal of Engineering Research and Technology*. 2015 Aug; 4(1).