Eco-Friendly Production of Paver Tiles Using Overburden Quartzite and its Feasibility as a Construction Material

Tshering Cheki[1*], Namgay Wangchuk[1], Penjor[1], Phub Zam[1], Sonam Wangay[1]

[1] *Civil Engineering Department, College of Science and Technology, Rinchending: Bhutan,*
**email: tsheringcheki.cst@rub.edu.bt*

Abstract: The growing amount of waste is a global concern especially in developing countries where only a small portion of already limited resources is allocated for its management. Mine waste generated from excavation, dressing and processing of minerals and plastic wastes are amongst the major concerns of the environmentalists owing to its huge environmental impact. Druk Mining at Kamji under Chhukha dzongkhag which is amongst the few active quartzite mines in Bhutan also faces problems due to discarded low quality quartzite. So, this provides an opportunity to explore the feasibility of production of tiles from discarded quartzite in combination with cement and polyethylene terephthalate (PET) as a binder. PET is the cheapest and readily available material whose addition increases the impact strength as well as the flexural strength. In this paper two binders were used in the production of tiles, PET and cement, in content of varying percentage. Plastic was utilized due to its abundance in the waste collection points and landfills. Tiles of size 200mm x 200mm x 20mm were produced with varying binder percentage from 10% to 70% with constant increment of 10%. Tests were conducted on the tiles for compressive strength, flexural strength, water absorption and density. Results indicates the ideal binder percentage for cement tile was 40% which had maximum 28 days compressive strength of 26.90MPa. The maximum compressive strength of 26.42MPa is exhibited by ideal binder percentage of 30% for PET tiles. The ideal tiles in comparison with locally available commercial tiles and IS specifications for physical and mechanical properties confirm that the tiles produced possess comparable properties and thus, it can be used as an alternative to the commercially available tiles.

Key Words: *PET, Quartzite, Tiles, Binder, Compressive strength, flexural strength*

Introduction

Bhutan's rich reserve of mineral resource is a blessing that often translates to significant wealth for the country. Mining activities in Bhutan began with induction of planned development in the 1970s and increase in demand for minerals and raw materials has led to further expansion of the mining activities. As of 2015, more than 163 mines were being leased and 48 active mines and quarries were currently operational in Bhutan (National Council of Bhutan, 2015). Despite proper planning of mines and mining strategies in Bhutan, mine waste is still a major concern with the annual global production of mine waste amounting to 70 billion tonnes annually which is the highest (Vivoda & Fulcher, 2017). The annual global production of plastic waste is already more than 100 million tonnes a year which eventually ends up as waste. Asia alone consumes 30% of the global plastic with an average of 20kg per person per year. As per World Economic Forum (2018) only 16% of the plastic produced was recycled from the 2% which was recyclable. The rest was burned, buried and stored in landfills of which 32% caused environment pollution (Hidayat et al., 2019). The size of mining activities and the sectors dependent on mining for a country with abundant natural resources signifies "that it dominates not only specific local areas, their economies, the communities and surrounding environment, but has also implications for the country as a whole: its economic structure, governance and ultimately, its development path" (Obasanjo et al., 2017).

Literature Review

Quartzite is one of the minerals mined in Bhutan that has a total of 5.18 million tonnes proven reserves. This is mined from 3 quartzite mines and the remaining 3 are currently non-operational (Anti-corruption Commission, 2016). The active mines are located at Dharbra (Chengmari under Samtse dzongkhag), Omchina (Kamji under Chhukha dzongkhag) and Tintale quartzite mine under Samtse dzongkhag. The quartzite mined from these mines is primarily supplied to the Ferro-silica industries within the country and the rest is exported to Bangladesh (National Council of Bhutan, 2015). The quartzite mines have seen a decrease in the production from 0.11 million tonnes in 2010 to 0.09 million tonnes in 2016. Annually on an average, 0.07 million tonnes of quartzite are extracted. As of 2016, the estimated quartzite resources are 4.54 million tonnes according to Annual Environmental Accounts 2017.

The annual global production of plastic waste is already more than 100 million tonnes a year which eventually ends up as waste. Asia alone consumes 30% of the global plastic with an average of 20kg per person per year. As per World Economic Forum, 2018 only 16% of the plastic produced was recycled from the 2% which was recyclable. The rest was burned, buried and stored in landfills of which 32% caused environment pollution (Hidayat et al., 2019). As per a study carried out by Anngraini et. al. (2018), there was a decrease in density by about 57% when plastic replaced the fine aggregate by 50%, which leads to an overall decrease in density of the mixture. Al-Azzawi (2016), found that the recycling of aggregates helped cut down costs associated with the waste management. The global construction industry alone consumes about 50% of total mineral reserves of the world. 35% of these minerals end up discarded in the landfills. In addition to the reduction in extraction of new material and waste reduction the economic benefit is enormous. The reduction and reuse of only 5% of the construction waste in UK alone could help save about £130 million (Ajayi et al., 2015). The per capita production of waste in Bhutan has already crossed 0.23 kg/day with more than 172.16 tonnes of waste generated per day. Plastics alone comprise 17.1% of the total waste (Waste & Survey, 2019). The trend of reuse of waste material as building and construction materials is on the rise. Waste is used as backfill material, for production of cement and concrete and production of tiles depending upon the geotechnical, mineralogical and geochemical characteristics of the waste (Lottermoser, 2011). The partial replacement of natural aggregates with the recycled material inserts waste materials into an alternative productive cycle which is an alternative recovery option with both environmental and economic benefits. The process of recovery and recycling is the best environmental solution to save raw materials and to reduce the amount of industrial waste generated, and consequently the contamination of the environment (Rodrigues et al., 2012).

Plastic waste is a problem in Bhutan like in any other growing economy. Although plastic is a highly useful material with ever increasing use in different fields, it has a negative impact on the environment by causing land, water and air pollution. Plastic waste amounts to around 55% of the overall waste generated annually. In 2010 alone 275 million tonnes of plastic ended up as waste although the annual production that year only amounted to 270 million tonnes. This was due to the remains of the plastic waste from the previous years. The annual consumption of PET bottles has already crossed 250,000 million in 20, weighing about 10 million tonnes. The average Bhutanese household in the urban areas generated 0.96 kg per household in a day and the overall waste generated was 0.25 kg per day per capita. The average waste generated per day was 2.36 kg for non-household waste, 1.44 kg per day for office and 0.33 kg per employee per day for commercial establishment (Phuntsho et al., 2010). Phuentsholing Thromde alone generates about 15 to 20 tonnes of solid wastes daily exclusive of the illegally dumped wastes. Plastic waste constitutes about 8 - 9% of 300 to 400 kg waste (BBS, 2012).

Mine waste is the large volume of discarded material that finds its origin in processes such as excavation, dressing and physical and chemical refinements of the minerals which are crucial in the processes of mining. This leads to deposition of a huge amount of waste generated from the excavation of the metallic and non-metallic materials by methods of opencast and deep shafts (Szczepańska & Twardowska, 2014).

Waste rock/ overburden is the unused extracted material from mines that is stored at the mine site or close by area for economic reasons. The Druk Mining at Omchina, Kamji follows opencast mining which as a rule generates more mining waste than underground mining. Constant mining at Omchina has led to production of large sum of overburden waste. The overburden produced were neither allowed to be exported to other countries nor allowed to be used for construction purposes. This led to disposal of overburden in nearby dumping areas leading to congestion and environmental pollution. As per the mining head, there is an approximate production of two trucks of overburden for every truck with good quality quartzite. Though there has been comprehensive studies on the possibility of use of waste rocks as backfill, landscaping material, and aggregate in road construction, not much effort has been put to combat the actual mine waste problem in Bhutan. So, this research aims to test and examine the feasibility of eco-friendly production of engineered products from quartzite in combination with plastic waste and cement to combat the generation of waste problem at the site.

Experimental Methodology, Materials and Method of sample preparation

The quartzite was collected from the landfill located at Druk Mining at Kamji which is about 30 km away from Pasakha under Chhukha Dzongkhag. The PET binder was collected from the waste collection points in and around College of Science and Technology, Rinchending. Locally available Portland Pozzolana Cement (PPC) was used as a binder too.

Using Cement as a Binder

The quartzite was crushed into powder and passed through 1.18mm Indian Standard (IS) sieve. The sample tile was produced using cement binder in combination with natural sand which is locally available and quartzite in a mould of size 200mm x 200mm x 20mm. PPC cement was used as a binder. The cement, sand and quartzite powder are measured by weight. The percentage of cement content in mixture is increased at a constant rate (0%, 10%, 20%, 30%, 40%, 50%, 60% and 70%). The percentage in terms of weight of the cement to aggregate include: 10:90, 20:80, 30:70, 40:60, 50:50, 60:40 and 70:30 where the sand is partially replaced by 67% of quartzite ratio of sand to quartzite is 1:2 as indicated in Table 1.

Table 1. Mix proportion of tiles produced

Binder to Aggregate percentage	Binder	Aggregate	
	Cement(g)	**Sand(g)**	**Quartzite(g)**
10:90	140	420	840
20:80	280	373	747
30:70	420	327	653
40:60	560	280	560
50:50	700	233	467
60:40	840	187	373
70:30	980	140	280

The aggregates that are measured in the proper ratios were thoroughly mixed with the help of trowel. The water was gradually added to the mixture and mixed thoroughly with the help of spade and trowel. The thoroughly mixed mixture was placed in the customized mould of size 200 mm x 200 mm x 20mm. The moulds were then vibrated to remove entrapped air. After the mould was completely prepared, it was allowed to set for 24 hours. The mould was then removed and the tiles were placed in water for curing as shown in Figure 1.

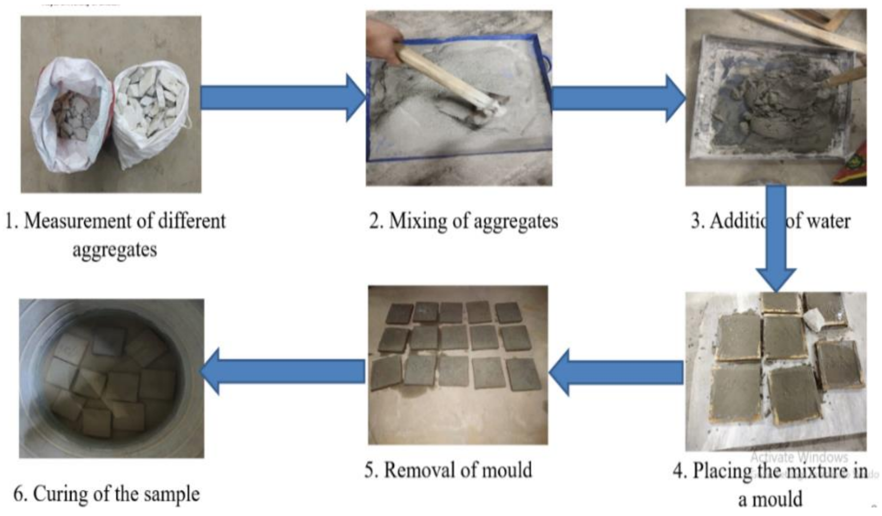

Figure 1. Production of tiles using cement binder

The binder percentage ranges from 10% to 70% with a constant increment of 10% for both types of samples. The mix was transferred into a lubricated mould and allowed to set for 24 hours. The tile was cured in water for 28 days for further examination and tests. Similarly, the plastic tile was made with the same percentage of PET binder as that of cement binder (Table 2). The PET bottles were cut into smaller manageable pieces so that it melts uniformly when heated. The aggregates, sand and quartzite, were however added to the PET at glass transition temperature. The mix was transferred to a mould where it was allowed to set and then removed. It was allowed to cool in open air. This type of curing is called ambient curing. Once the mixture was set and cooled down to a safe temperature, the mould was removed, ensuring that there were no breakages in the sample, and the tiles as shown in Figure 2 were placed in water for curing. Figure 3 shows the final product of the tiles produced after 28 days of curing ready for the test analysis.

Table 2. Percentage content of PET Binder

Binder to Aggregate Percentage	**Binder**	**Aggregate**	
	PET(g)	**Sand(g)**	**Quartzite(g)**
10:90	140	420	840
20:80	280	373	747
30:70	420	327	653
40:60	560	280	560
50:50	700	233	467
60:40	840	187	373
70:30	980	140	280

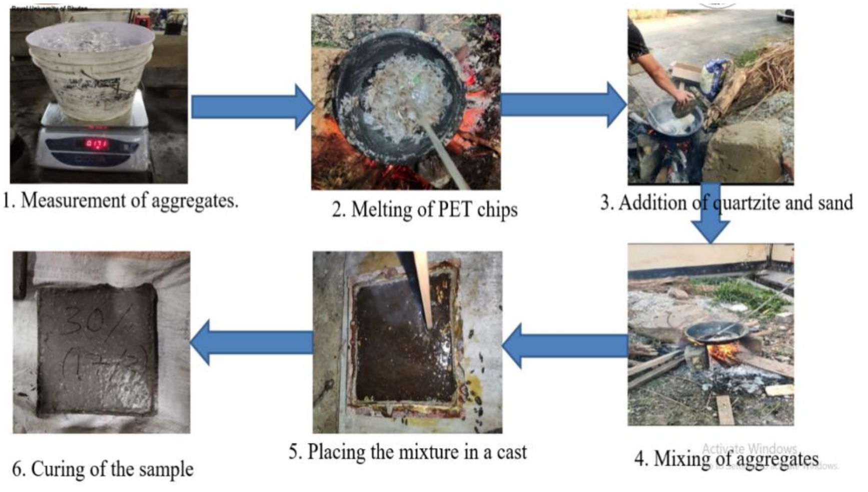

Figure 2. Production of tiles using PET binder.

(a) **(b)**

Figure 3. Tiles produced (a) Cement binder tile; (b) PET binder tile

Material Testing

Aggregate Crushing Value Test

The aggregate crushing value gives the relative measure of the resistance of the aggregate to crushing under gradually applied compressive load. This test was used to determine the suitability of the aggregate to as a construction material. This test was conducted according to IS: 2386 (Part IV)-1993. For the aggregates of crushing value 30% or higher the result is not valid thus the 10% fines should be determined in place of it. The test indicates the strength of the aggregate. Lower value of aggregate crushing value indicates higher strength and as the value increases, the strength of the aggregate decreases. The crushing value of the quartzite was found to be 21.52% which indicated that the aggregate was strong and suitable to be used as an aggregate.

Aggregate Impact Value Test

The aggregate impact test determines the resilience to a sudden impact of an aggregate. The property of a material to resist impact is also known as toughness. The value also determines the aggregate's ability to resist crack deformation in repetitive impacts such as road movement. Therefore, the aggregates should have sufficient toughness to withstand their breakdown due to impact. The aggregate impact value is a measure of sudden shock resistance, which can vary from its resistance to compressive loads applied gradually. The test was performed conforming to IS: 2386 (Part IV)-1993. The aggregates are graded as toughness based on the importance as mentioned below. The aggregate impact value of the aggregate was found to be 11.6% which lies between 10-20%. This indicated to a strong aggregate that can resist sudden impact loads. The aggregate was tough and was suitable to be used as an aggregate.

Aggregate Abrasion Test

This test determines the abrasion value of the coarse aggregate. Resistance to wear or hardness is an essential property of the aggregate when used in surface courses. Abrasion test is carried out by of the following methods;

1. Deval abrasion test and
2. Los Angeles abrasion test

The Los Angeles Abrasion test was adopted out of the two methods. There are seven standardized grading categories based on the size of aggregates and accordingly the number of abrasive charge and revolution of the machine differs. This test was also performed based on IS: 2386 (part IV)-1993. The aggregate abrasion value of the aggregate was found to be 31.5% which indicated that it had a high resistance to abrasion. Thus the aggregate was found to be hard enough to be suitably used as an aggregate.

Sample Test and Result Analysis

Compressive Strength Test

The samples were subjected to a compression test as per IS 15658: 2006 in order to determine the compressive strength of the samples. Tests were done (Figure 4) to decide the compressive strength at various stages of curing 7, 14 and 28 days. The samples that were tested after 7 days of curing showed that they gained about 85% of the maximum strength. The samples gained on average about 90% strength after 14 days curing when compared to the strength after 28 days. The sample's compressive strength increased for up to 40% cement content in the mixture. However, the sample showed a steady reduction in strength with the percentage increase in cement content beyond that. The 40% cement sample displayed the maximum compressive strength of 26.90 MPa while the sample containing 20% cement showed the minimum strength of 24.80 MPa as shown in Figure 5. The compressive strength of the sample displayed an increase with increase in PET percentage up to 30% after which the compressive strength decreased. However, samples with 40% PET have compressive strength almost equal to samples with 30% cement binder. Hence tile samples produced with 30% PET binder and 40% cement binders are stronger as shown in Figure 6.

Figure 4. Compression Test of Sample.

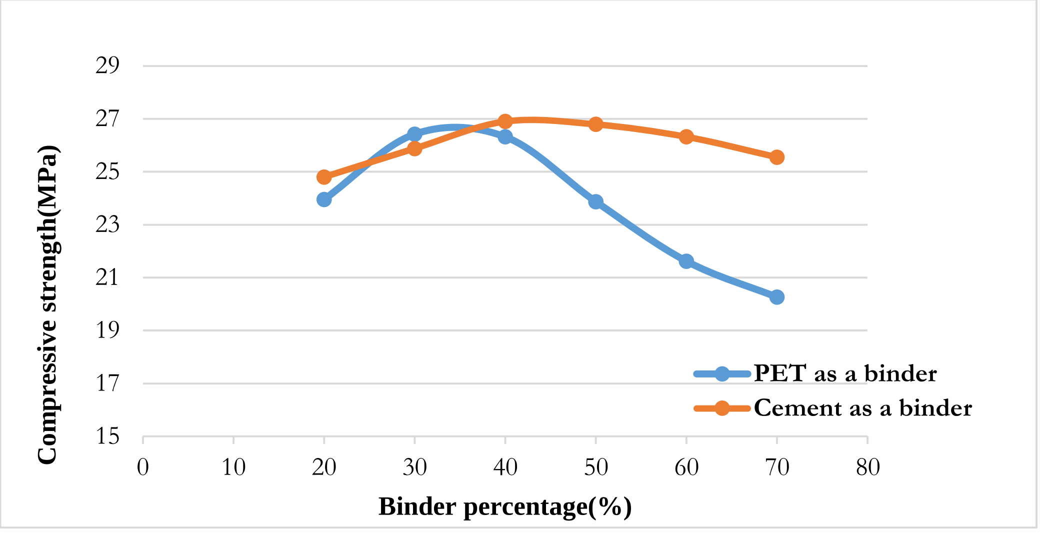

Figure 5. Compressive Strength Test Result of tile Samples Produced.

Flexural Strength Test

The samples were subjected to flexural load as per IS 15658: 2006 to determine the behavior of the samples under the effect load. It gives idea on how much deformation it can undergo by yielding and also to find the bending properties of materials. Sometimes it is called transverse strength test. In addition, through the failure modes of specimen, analyst can assess the types of failure undergone and mitigation measures can be developed. The flexural strength and the average breaking load increased with increase in the binder percentage for both the tile samples. It was found that the flexural strength of ideal cement tile (40%) and plastic tile (30%) were 48.78 MPa and 40.32 MPa respectively (Figure 6). Commercial tiles such as Coral stone and Anti-skid have their flexural strength of 10.97 MPa and 40.86 MPa respectively.

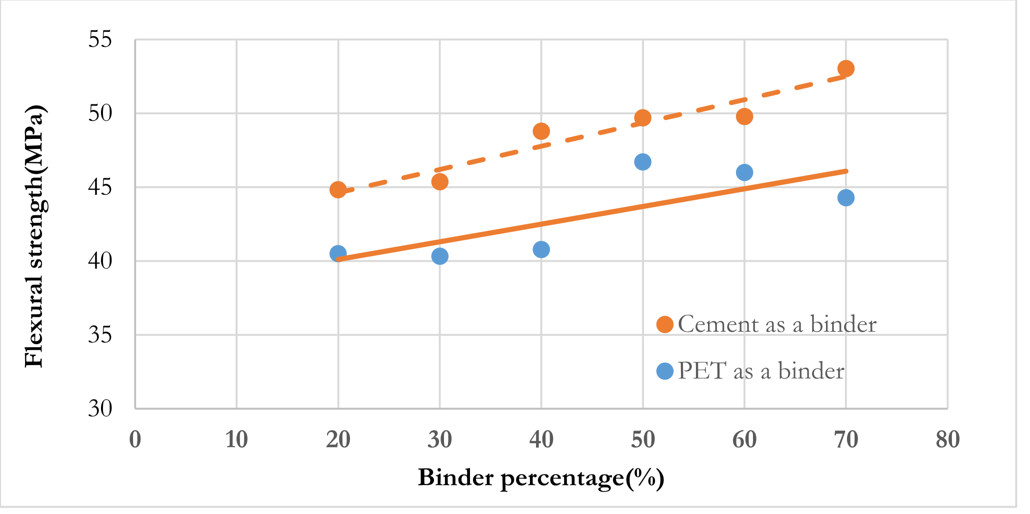

Figure 6. Flexural Strength Test Result of tile Samples Produced.

Water Absorption

The water absorption of the tiles was determined as per IS 15658:2006. In this, the tiles are first weighed in dry condition and then in wet conditions. The difference between the dry weight and saturated weight is calculated in percentage. The water absorption decreases with increase in the amount of cement. From the experiment conducted, tile samples with 20% cement and 70% PET were found to have highest water absorption (2.61% and 2.03%) and tile samples with 70% cement and 40% PET were found to have the lowest water absorption (1.75% and 1.31%) as shown in the Figure 7. Lower water absorption usually translates to higher strength and durability. It also represents a highly compacted sample with very less voids thus less permeability.

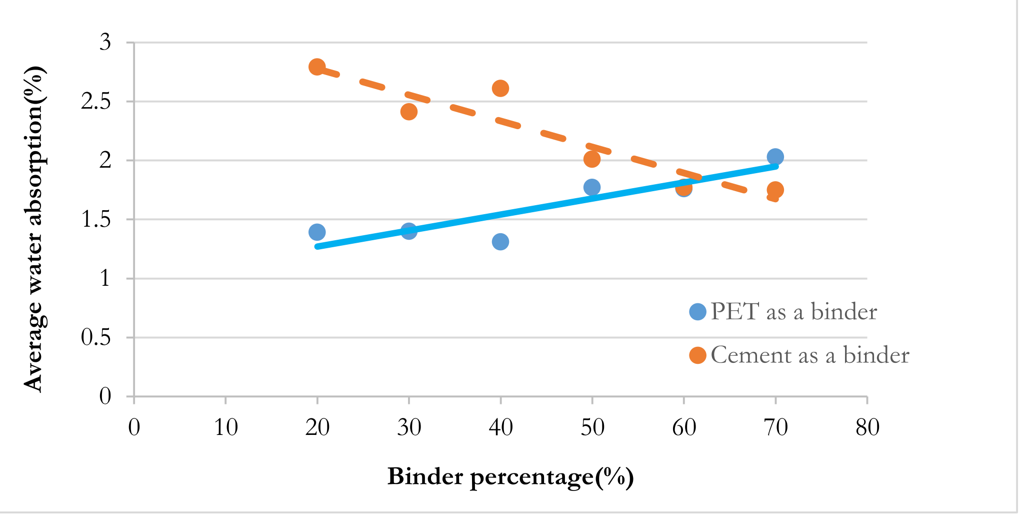

Figure 7. Water Absorption Test Result of tile Samples Produced.

Density

This was determined as per IS 1237:2012. The density of the tile sample is calculated by dividing the dry weight of tile by the volume of the sample. Two samples of each percentage were made and average dry weight was taken. Figure 8 shows that density increased with increase in cement content. Higher density indicates highly compacted samples with lesser voids hence lesser permeability and higher strength. From the result, the tile samples with 70% cement were found to have highest average density (2815.63kg/m^3) and the sample with 20% cement was found to have lowest average density (2319.38kg/m^3). Sample tiles of PET binder exhibited a maximum average density of 1611.88 kg/m^3 for 20% sample and minimum of 1129.38 kg/m^3 for 70% sample.

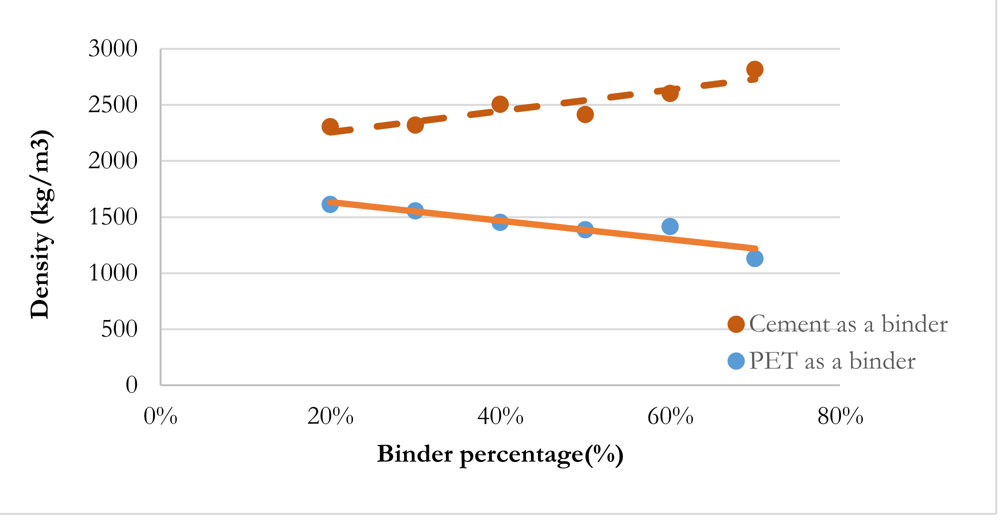

Figure 8. Density v/s Binder percentage

Comparison with Commercial tiles

On comparing these samples with commercially available tiles like coral stones and anti-skid (leather), the difference in the value was not much. In fact some of the samples exhibited a higher value of strength. For example, coral stone tiles have a lower compressive strength and flexural strength of 22.86 MPa and 10.97 MPa respectively as indicated in Figure 9 and Figure 10. The weight variation of sample tiles (40% cement and 30% PET) with cement and PET as binder with respect to commercially made tiles such as coral and anti-skied are quite significant. The weight reduction of sample by 40% cement with respect to coral stone is 18.10% and the weight reduction of sample by 30% PET with respect to coral stone is 49.14%. The weight variation of sample with 40% cement and 30% PET with respect to anti skied are -22% and 24.15% respectively. The paving blocks compressive strength at 28 days is 30 MPa for non-traffic, and 35 MPa for traffic condition, according to IS

15658-2006. For this analysis the compressive strength of all the tile samples lies below 30 MPa. However, the minimum compressive strength for light traffic is 25 MPa with respect to SANS: 1058-2012 as Agyeman, 2019. The tiles produced can therefore be considered suitable for non-traffic and light traffic use as paving tiles.

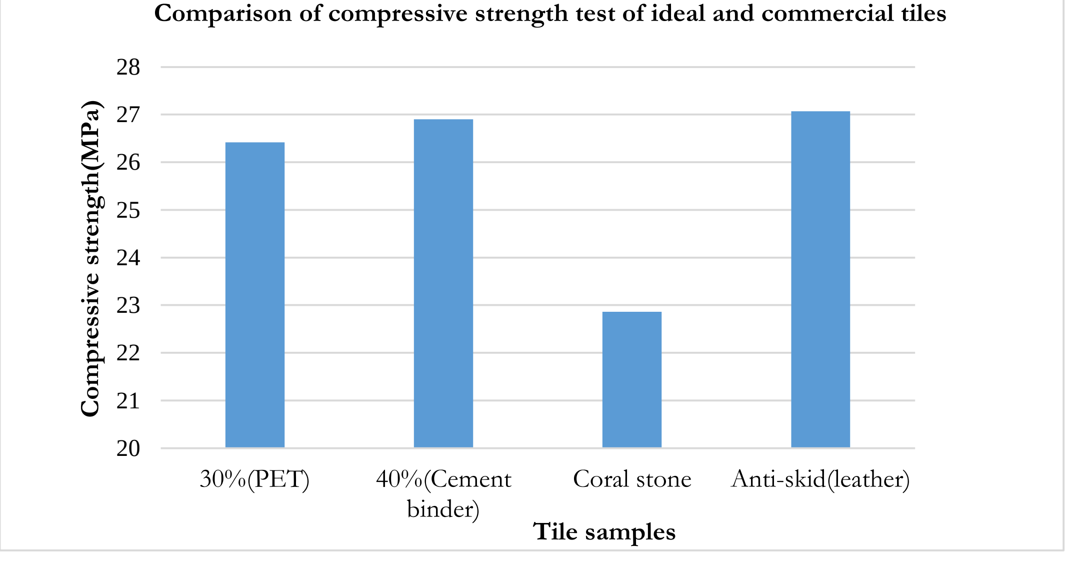

Figure 9. Compressive Strength Test Result of Ideal Tiles and Commercial Paver Tiles.

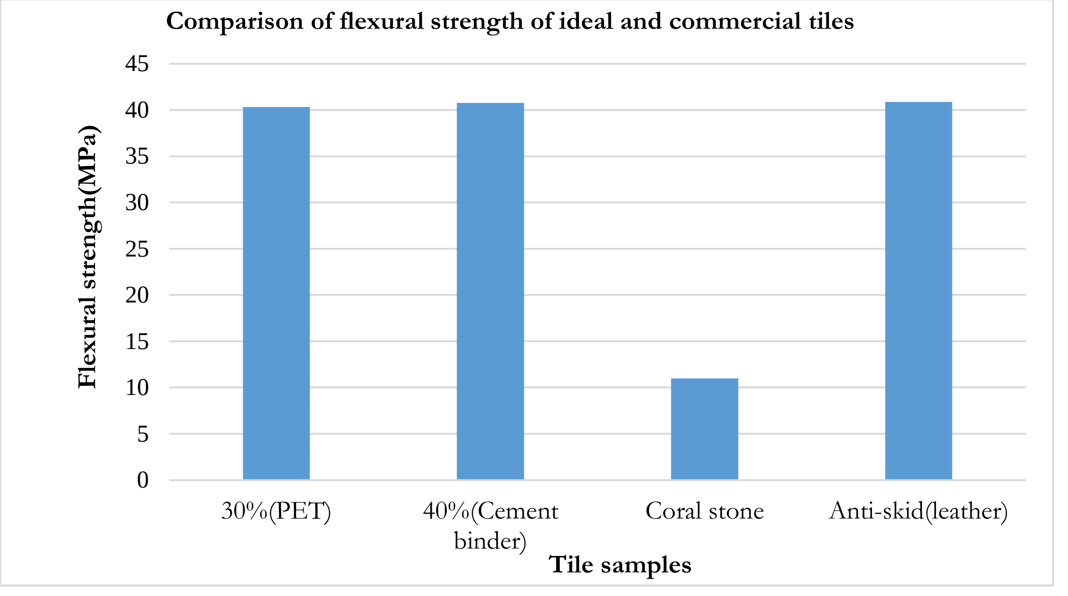

Figure 10. Flexural Strength Test Result of Ideal Tiles and Commercial Paver Tiles.

According to a comparative analysis by Hardikar et al. (2019) of tiles produced from reusable Low-Density Polyethylene plastic waste, the highest compressive strength was found to be 17.26 MPa. Compared to the test result, this study that used plastic and cement as binder demonstrated higher strength. With reference to IS: 1237: 2012, the average water absorption percentage should not be more than 10%. Nonetheless, the average percentage of water absorption for all tile samples produced with different mix proportions is within the limit when comparing with average water absorption of commercially available tiles and water absorption in this study is approximately five times higher. The density of a tile according to IS 1237:2012 shall not be less than 1500 kg/m^3. The density of sample with varying cement ratios is above 1500 kg/m^3. However, densities of tiles with PET as binder are lower, except for 20 and 30 percent PET samples. As per IS: 1237-2012 the minimum breaking load shall not be less than 1500 N and the flexural strength shall not be less than 3 MPa. However, flexure strength of 30% PET and 40% cement are 63.70 MPa and 76.22 MPa respectively; which is within the acceptable range. In addition, on comparing with commercial tiles: Coral stone and Anti-skid (leather) with flexural strength 10.97 MPa and 40.86 MPa respectively; ideal tiles flexural strength is comparable to commercially available tiles.

Conclusion

Waste is a huge problem in Bhutan as much as it is in other parts of the globe. The dumping of waste rock and plastic is rising annually. This is a serious threat that can lead to degradation of the pristine environment and harm the living organisms that are already endangered. Thus, utilizing these waste materials in production of construction material which is a booming industry in the country is a way of tackling the waste problem and other environmental problems associated with it. Thus, proving the production of tiles with recycled material is very eco-friendly. Tiles in Bhutan are largely imported from India because the local industry is unable to meet the market demand and achieve the required specifications. The production of tiles from the waste rock from the quartzite mine and plastic from landfills helps provide an alternative to the imported tiles for construction purposes. Tiles are generally produced from cement, clay and natural aggregates. After review of works on similar topics the group came up with the idea to incorporate waste rock from quartzite mine at Kamji with cement and PET waste from the landfills as binder to combat the aforementioned problems. The binder ratio was varied to find the ideal binder ratio for tile with best mechanical and physical properties.

Following are the result obtained:

1. The ideal tile for binder ratio ranging from 10% to 70% is:
    - Tile with cement as Binder: 40% with compressive strength of 26.90 MPa.
    - Tile with PET as Binder: 30% with compressive strength 26.42 MPa.
2. The material testing revealed that the quartzite overburden has an aggregate crushing value, aggregate impact value and abrasion value of 21.52%, 11.6% and 31.5% respectively. Thus, it can be used as a coarse aggregate in building and also as a backfill material.
3. Quartzite can be used for both traffic and non-traffic conditions because of its high compressive strength, impact resistance and high abrasion resistance.
4. Plastic has low density, excellent chemical resistance and is cheap and easily available. Thus, the use of plastic as a binder is feasible.
5. The tiles produced with the use of the recycled material exhibited comparable properties with the locally available tiles. Thus, it can be used as an alternative to the commercially available tiles.

Recommendations

Waste rock such as quartzite can be used in production of various construction materials like tiles. So, the feasibility of the use of the waste rock for other engineering works can be further explored. Explore the feasibility of other types of plastic such as Low-Density Polyethylene, Polypropylene and High-Density Polyethylene as a binder. This project is focused on the physical characteristic of the sample, so further studies can be carried out on the chemical properties. Samples with high percentage of PET upon cooling undergo rapid deformation. So, the means to regulate temperature and measures to control the emission can be further explored to obtain better quality products. Quartzite was utilized as a fine aggregate in this project. The use of quartzite in the form of coarse aggregate and its influence on the properties of tile can be studied upon.

Acknowledgement: The authors would like to thank College of Science and Technology for the test facilities. Our heartfelt gratitude goes to all the people who are directly and indirectly involved in making this research a successful journey. The data are the record of the project carried out by authors.

Funding: The preparation of this manuscript did not receive any direct fundings.

Conflict of Interest: The authors declare no conflict of interest.

References

Ajayi, S. O., Oyedele, L. O., Bilal, M., Akinade, O. O., Alaka, H. A., Owolabi, H. A., & Kadiri, K. O. (2015). Waste effectiveness of the construction industry: Understanding the impediments and requisites for improvements. *Resources, Conservation and Recycling*, *102*, 101–112. https://doi.org/10.1016/j.resconrec.2015.06.001

Al-Azzawi, A. (2016). Mechanical properties of recycled aggregate concrete. *Journal of Engineering and Applied Sciences*, *11*(02).

Anggraini, V., Paul, S., Babafemi, A. J., & Šavija, B. (2018). Engineering Properties of Concrete with Waste Recycled Plastic: A Review. *Sustainability*, *10*. https://doi.org/10.3390/su10113875

Anti-corruption Commission. (2016). *Improving Business Environment : The case of the Mining Industry in Bhutan* (Issue April).

Comission, E. (2011). *Plastic Waste : Ecological and Human Health Impacts* (Issue November).

Contreras, I. N., Bader, J., DuRant, P., & Grafman, L. (2018). An Analysis of Recycling High Density Polyethylene with Limited Resources. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, *13*(2), 45–68. https://doi.org/10.24908/ijsle.v13i2.11621

Dorji, S. (2018). *Plastic Pollution and its Adverse Impact on Environment and Ecosystem*. http://www.technicaljournalsonline.com/ijaers/

Drakpa, L., Deki, T., Subba, S., Kuenchap, P., & Norbu, C. (2019). *Comparative analysis on normal concrete and recycled aggregate concrete re inforced with polypropylene (pp) fibres* (Issue June).

Godfrey, L. (2019). Waste plastic, the challenge facing developing countries Ban it, change it, collect it? *Recycling*, *4*(1), 2–7. https://doi.org/10.3390/recycling4010003

Hidayat, Y. A., Kiranamahsa, S., & Zamal, M. A. (2019). A study of plastic waste management effectiveness in Indonesia industries. *AIMS Energy*, *7*(3), 350–370. https://doi.org/10.3934/ENERGY.2019.3.350

Lottermoser, B. G. (2011). Recycling, reuse and rehabilitation of mine wastes. *Elements*, *7*(6), 405–410. https://doi.org/10.2113/gselements.7.6.405

MOF. (2018). *Trade Statistics of Japan Ministry of Finance*. http://www.customs.go.jp/toukei/info/tsdl_e.htm

Momoh, J., Opaluwah, A., & Albeera, H. (2018). Challenges facing nigeria's urban environment: the abuja case. *Journal of Sustainable Development in Africa*, *20*(2), 34–49.

National Council. (2013). *Socio-economic and environmental impact assessment of mining and quarrying activities in Bhutan*. *February*.

Obasanjo, P., & Founda, B. (2017). Development. *Great Insights*, *6*(3).

Rodrigues, R., L. Santana, L. N., Arajo, G., & Carlos, H. (2012). Recycling of Mine Wastes as Ceramic Raw Materials: An Alternative to Avoid Environmental Contamination. *Environmental Contamination*. https://doi.org/10.5772/31913

Shareef, U., Raju, S. S. S. ., & Chelela, V. (2019). Study on the utilisation of quartzite as a replacement for coarse aggregate in concrete. *International Journal of Environment and Waste Management*, *24*, 107. https://doi.org/10.1504/IJEWM.2019.100664

Standards, B. of I. (1963a). *IS 2386-3 (1963): Methods of test for aggregates for concrete, Part 3: Specific gravity, density, voids, absorption and bulking [CED 2: Cement and Concrete]* (8th ed.). Bureau of Indian Standards.

Standards, B. of I. (1963b). *IS 2386-4 (1963): Methods of test for aggregates for* *concrete, Part 4: Mechanical properties [CED 2: Cement and Concrete]* (B. of I. Standards (ed.); 10th ed.). Bureau of Indian Standards.

Standards, B. of I. (1970). *IS 383 (1970): Specification for Coarse and Fine Aggregates From Natural Sources For Concrete [CED 2: Cement and Concrete]* (B. of I. Standards (ed.); 2nd ed.). Bureau of Indian Standards.

Standards, B. of I. (1988). *IS 4031-6 (1988): Methods of physical tests for hydraulic cement, Part 6: Determination of compressive strength of hydraulic cement (other than masonry cement) [CED 2: Cement and Concrete]* (B. of I. Standards (ed.); 4th ed.). Bureau of Indian Standards.

Standards, B. of I. (2006). *IS 15658 (2006): Precast concrete blocks for paving - [CED 5: Flooring, Wall Finishing and Roofing]* (B. of I. Standards (ed.); 1st ed., Issue 1). Bureau of Indian Standards.

Sule, J., Emmanuel, S., Joseph, I., Ibhadode, O., Alfred, B. Y., Waziri, F. I., & Sunny, E. (2017). Use of Waste Plastics in Cement-Based Composite for Lightweight Concrete Production. *International Journal Of Research in Engineering Technology*, *2*(5), 44–54. https://doi.org/October 2017

Szczepańska, J., & Twardowska, I. (2014). Distribution and environmental impact of coal mining wastes in Upper Silesia, Poland. *Environmental Geology*, *38*(3), 249–258. https://doi.org/CE300-0009/12

Vivoda, V., & Fulcher, J. (2017). *Mine Waste Classification and Management. February.*

Wangdi, S. (2012, May 7). Phuentsholing's growing solid waste management problem. *BBS*.