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Experimental Analysis on Optimum Use of Filler Materials of River Bed Sub Base Sample for Pavement

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Abstract

Composition of different layers to resist the traffic load as per design on the flexible pavement, among them subbase is one. This research carried out to optimization of filler sample on riverbed sub-base material whose plastic index is nil. The sub-base material plays a pivotal role in supporting the overlying pavement structure, and optimizing its properties is essential for enhancing overall pavement performance The observations through laboratory testing and trials ensure the modified sub-base material meets the necessary performance criteria. The study aims to contribute valuable insights into sustainable and effective pavement construction practices and presents an experimental analysis focused on improving riverbed sub-base material through the optimal utilization of filler materials. During laboratory trials all necessary requirement, like gradation, plastic index, specific gravity, maximum dry density and California bearing ration are observed. From laboratory trials 10% threshold appears to be a critical point where the material satisfies the specified requirements, define by Government of Nepal, Department of Road, Standard Specification for Road and Bridges-2073 (with second abdmanent-2078). Regular quality control and testing during construction are essential to confirm that the material consistently meets the desired specifications. Additionally, collaboration with geotechnical engineers and adherence to local standards and guidelines are crucial in ensuring the long-term performance of road constructions.

Keywords: *Filler Sample, Optimization, Specification, Sub Base.*

1. Introduction

A well properly compacted sub base layer of flexible pavement is crucial for the long-term impact. The construction and maintenance of road infrastructure are critical aspects of urban development and transportation. Flexible pavements, known for their capacity to distribute loads efficiently, depend on a sturdy sub-base material to ensure stability and longevity. Riverbed materials are often utilized as sub-base due to their availability, but enhancing their mechanical properties is imperative for ensuring the longevity of flexible pavements. This article explores an experimental analysis focused on optimizing riverbed sub-base material by strategically incorporating filler materials. It should efficiently resist water penetration, provide stability, and distribute loads to ensure the strength of the whole pavement structure. The primary objectives of the study are to address existing challenges in pavement engineering, contribute to sustainable construction practices, and offer practical insights for the advancement of transportation infrastructure. In the long term, infrastructure development, including the upgrading of roads, is crucial for the economic growth and development of a country. It often involves finding sustainable resolutions that balance the necessity for transportation infrastructure with eco-friendly and economic reflections.

This research was conducted to optimized the filler material on sub base so that to fulfill the specification prescribed by Department of Road government of Nepal. All the tested data are compared with specification. The objective of research was geotechnical properties of sub base material by optimizing the filler material as specified by Department of Road Standard Specification for Road and Bridge 2078.

O'Flaherty, C.A (2001) Stated that the prime function of the granular sub-base is to provide uniform support to the base course and compensating the inadequate subgrade strength rather than increasing the stability of the pavement. Saket Prasad (2016) have focused on optimizing road construction for various factors, including material consumption, construction speed, load distribution, and adaptability to challenging environmental conditions like water-logged areas. These resolutions suggest an emphasis on efficiency, cost-effectiveness, and environmental considerations in road infrastructure development.

Pranshul Sahu, Ritesh Kamble (2017). The paper seems to address the complex issues associated with flexible pavement design, encompassing both the material properties of different layers and the thickness design required to ensure the pavement's ability to bear loads effectively. It underscores the importance of understanding the interplay between material strength, durability, and thickness to create a resilient and functional flexible pavement system.

Lekarp, F., Isacsson, U., Dawson, A. (2000) reported that the deformation behavior of unbound aggregates under repeated traffic loading can be interpreted through their resilient response and availability of fines up to specific limit. However, these fines will have little effect on performance if the drainage conditions are excellent. Harsha Vardhan N. Shinde (2018) have conducted direct cost analysis for all these methods, likely comparing the financial implications of each approach. Additionally, they have evaluated the strength of the subgrade for various crust materials at different California Bearing Ratios (CBR). This analysis helps assess the ability of the road structure to withstand loading and provides insights into the performance of each construction method under different conditions. Overall, the study appears to be comprehensive, considering both cost factors and the structural strength of the road for different materials and construction techniques.

Ravi Kumar T, Sai Krishna K (2017) explained the stabilization method using cement can be applied in certain locations. The recommendation is to follow standard code provisions, suggesting that there are established guidelines or standards that can be followed for effective and reliable road construction using the stabilization method. the study outlines a systematic approach to soil stabilization for road construction, considering soil evaluation, suitability checks, mix design, construction procedures, and testing. The conclusion suggests the feasibility and applicability of the stabilization method in certain areas of India with low road densities, emphasizing the importance of adhering to established standards. Indian Road Congress (2012) stated that the manuals play a crucial role in guiding the design and maintenance of flexible pavements. They provide a structured approach, ensuring that construction is carried out with specific criteria, and maintenance is conducted systematically to maximize the lifespan and performance of the pavements.

Raad, L., Minassian, G.H., Gartin, S. (1997) have compared the effect of fines on the dynamic response for open and dense graded base courses and observed that, under saturated conditions, the damage probability for the pavement with open graded aggregates is lesser. This is owing to fact that they offer more resistance to pore pressure build-up than dense-graded aggregates. Ministry of Roads, Highways and Transport, 5th revision (2013); the guide manual seems to be a valuable resource for professionals involved in highway projects. It offers a systematic and detailed approach to various aspects of construction and maintenance, providing specific clauses for different components and works, facilitating efficient project management and execution. For the study of Cement Treated Sub Base / Cement Treated Base (CTSB/CTB) the clause no. 403 is useful. Also, for the maintenance work for flexible pavements the clause no. 3000 is helpful.

2. Method of Study

This research carried out on the basis of following flow chart and laboratory test. All the test result was compared with Standard Specification for Road Bridge 2078.

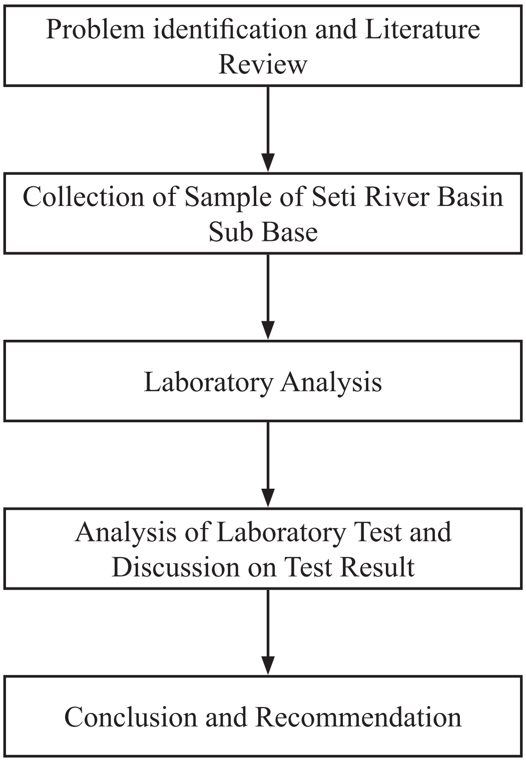

Fig. 1: Research methodology

Three specimen samples for each test of geotechnical properties were collected from Harpan Khola River Basin Pokhara-23, Kaski district of Nepal. Laboratory tests for the geotechnical properties of sample were carried out in laboratory which is calibrated and certified by the Government of Nepal, Nepal Bureau of Standards, for material testing. In this research, geotechnical properties of sampled sub base material were tested, the average value as obtained from collected samples was calculated and compared with Standard Specifications for Road and Bridge Works-2073 (with second amendment 2078) of Department of Road (DoR), Nepal.

Geotechnical properties of sample such as gradation, Specific gravity, Water Absorption, Aggregate Impact Value, Plastic Index, Maximum Dry Density and California Bearing Ratio sub base were carried out as per procedure specified in Manual for Standard Tests -2016 of Department of Roads, Nepal. The entire laboratory testing was conducted under normal temperature and pressure of laboratory as it's condition, seasonal variation on properties of sample, and geological properties of sub base sample was not taken into consideration.

3. Results and Discussions

During the research geotechnical properties of sub base naturally and an addition of filler material was carried out.

Geotechnical Properties of River Bed Sub Base and Filler Soil

Table 1: Properties of river bed sub base and filler soil geotechnical properties.

Description of Test	Obtain Results		Remarks
	River Bed Sub Base	Filler Soil	
Gradation	Type I	-	
Aggregate Impact Value	24.61 %	-	
Specific Gravity	2.64	2.457	
Liquid Limit	15.25%	43%	
Plastic Limit	0	37.5%	
Plastic Index	15.25%	5.5%	
Maximum Dry Density	2..244 gm/cc	1.643 gm/cc	
Optimum Moisture Content	6.8%	23%	
California Bearing Ratio	60.28%	6.718%	

From the above table we can say that riverbed sample has high plasticity index as prescribed by Standard Specifications for Road and Bridge Works-2073 (with second amendment 2078) of Department of Road (DoR), Nepal. Research focus on maintaining the plasticity index within the specified limits when using riverbed samples as filler in sub-base construction suggests a commitment to meeting these standards.

Geotechnical Properties with Addition of Filler Soil

Gradation

The percentages of various particles sizes in given dry sample are gradation of sub base. The arrangement of IS sieve as per the Standard Specification for Road and Bridge 2078. Arrangements are one over another in the order of their mesh openings, the largest sieve being kept at the top smallest sieve at bottom. Gradation of river bed sub base was carried on the basis of specification given in fig 2.0. with and without adding of filler material.

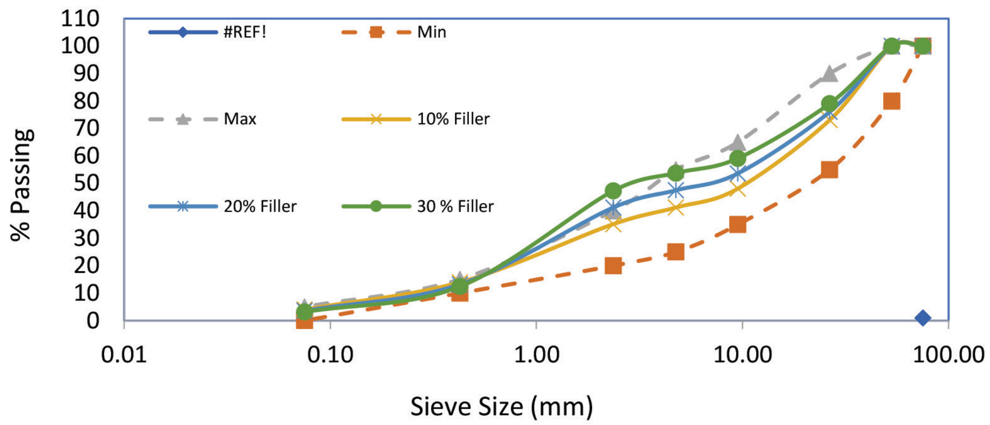

Fig. 2: Gradation curve of river bed gravel.

Above graph implies that the gradation of river bed gravel lies within the specification for road and bridges 2078 prescribed by department of road, standard specification for road and bridge 2078, section 2003-3 in type I. Without out addition of filler materials. But, in addition of filler on sub base gradation doesn't implies within the specification prescribed by department of road Nepal. The potential benefits or drawbacks of using this specific mix in terms of construction efficiency, cost-effectiveness, and long-term structural integrity.

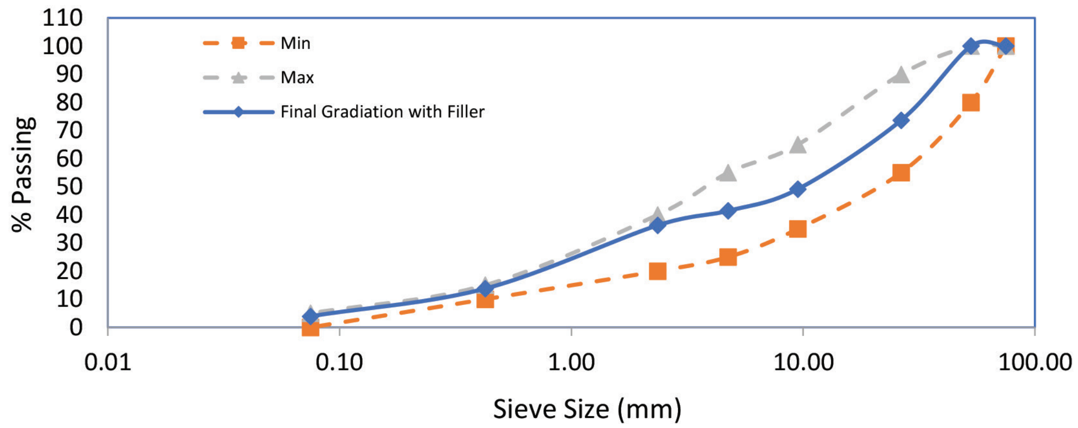

Fig. 3: Sub base material gradation with filler soil.

From the above graph we can use 10% filler soil to riverbed sub base, to specified the specification.

Specific Gravity

The specific gravity test helps in the identification of stone. Water absorption gives an idea of strength of aggregate. Specific Gravity shown in table 1

Table 2: Specific gravity and water absorption with and without filler material.

Specific Gravity as Per DoR Test Manual 2016				
Details	**Sub Base Material with and without filler material**			
Sample Name	**0%**	**10%**	**20%**	**30%**
Weight of Saturated Aggregate & Basket in Water (W1) gm	2228.50	2220.00	1859.00	1379.00

Weight of Basket in Water (W2) gm	789.00	789.00	789.00	789.00
Weight of Saturated Aggregate in Air (W3) gm	2303.00	2300.00	2005.00	1245.00
Weight of Oven Dry Aggregate in air (W4) gm	2283.00	2279.00	1975.00	1215.00
Sp Gravity = (W4) / [W3-(W1-W2)]	**2.64**	**2.62**	**2.11**	**1.85**
Specification	**2.5-3**			

Above table shows that the specific gravity doesn't lies within the limit define by department of road, standard specification for road and bridge-2078, with addition of filler soil at 10% and without addition of filler, only satisfied the specification prescribed by government of Nepal department of road

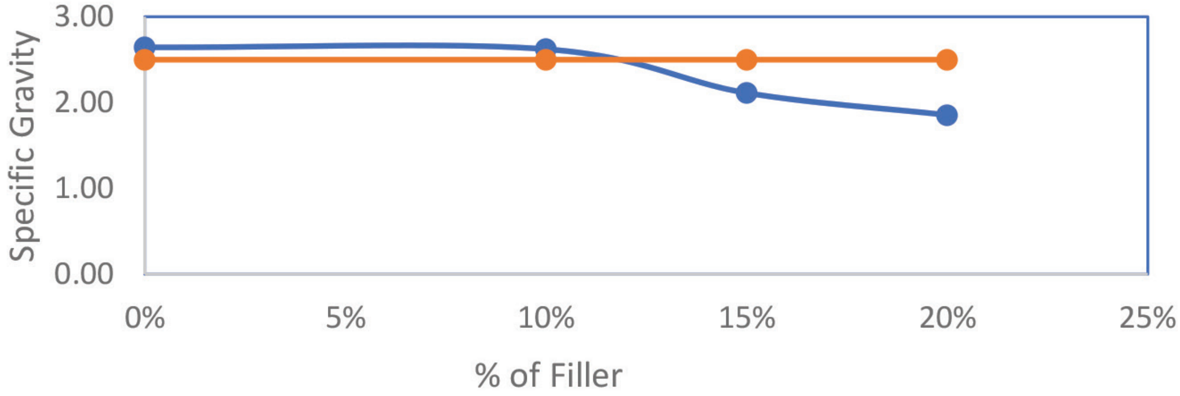

Fig. 4: Optimum use of filler sample to meet the specification

From, above figure the soil sample with 10% filler can be used to satisfy the minimum requirement of specific gravity, which is stated as 2.5. This suggests that the specific gravity of the soil sample meets or exceeds the specified minimum value according to your requirements or standards.

Liquid Limit (LL)

It is the water content corresponding to the arbitrary limit between liquid and plastic state of corresponding of a soil. It is defined as the minimum water content at which the soil is still in the liquid state, but has a small shearing strength against flowing which can be measured by standard available means.

Plastic Limit (PL)

It is the water content corresponding to an arbitrary limit between the plastic and the semi- solid state of consistency of a soil.

Plastic Index (PI)

The range of consistency within which a soil exhibits plastic properties is plastic index.

Table 3: Liquid limit, plastic limit and plasticity index with and without filler material

Liquid Limit, Plastic Limit and Plasticity Index as per DoR Test Manual 2016 and Specification 2078				
Detail	**0% Filler Sample**	**10% Filler Sample**	**20% Filler Sample**	**30% Filler Sample**
Liquid Limit (%)	15.25	15	18.5	20
Plastic Limit (%)	0	10	14.2	17.8
Plasticity Index (%)	15.25	5	4.3	2.82
Specified Value	Plastic Index Less Than 6%			

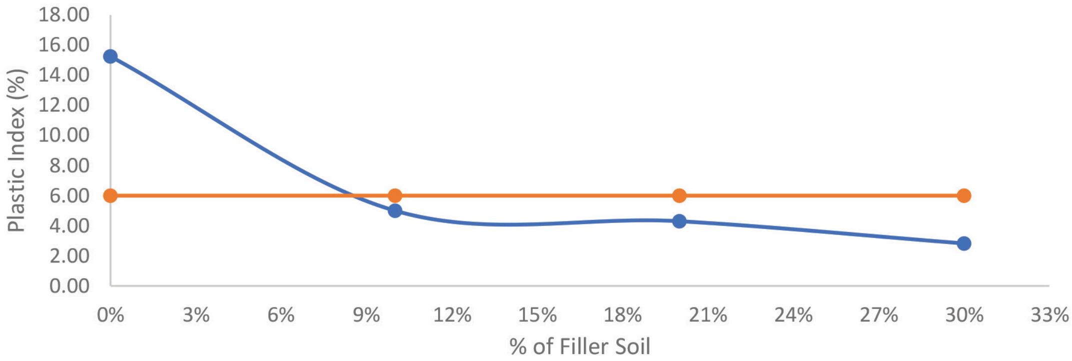

Fig. 5: Plastic index of sub base with and without addition of filler.

From the above graph also, we comply that at 12.25% fill sample can add to fulfill the required specification i.e., less than 6% of plastic index.

Maximum Dry Density and Optimum Moisture Content (MDD and OMC)

Compaction is a process by which the soil particles are artificially rearrange and packed together into a closer state of contact by mechanical means in order to decrease the porosity of the soil and thus increase its dry density. The compaction process may be accomplished by rolling, tamping, or vibration. A definite relationship between the soil water content and degree of dry density to which a soil might be compacted, and that for specific amount of compaction energy applied on the soil there was water content termed as optimum moisture content at which a particular soil attained maximum density. Proper compaction ensures the stability and load-bearing capacity of the soil, which is crucial for the success and longevity of structures built on or with the support of the compacted soil.

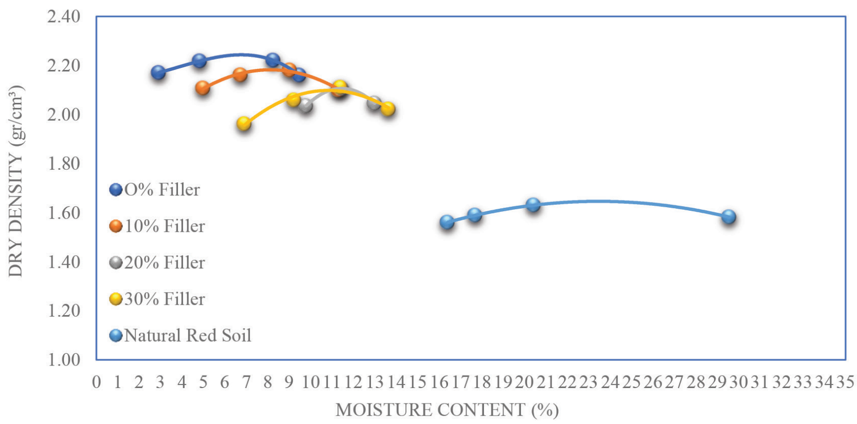

Fig 6: Maximum dry density and optimum moisture content of natural soil, river beds sub base and addition of natural soil as filler on river bed sub base

Above graph implies that the MDD at 0% filler material is 2.244 gm/cm3and OMC is 6.8% and natural soil as filler has MDD 1.643 gm/cm3and OMC 23%. The MDD of the river bed sub base material with filler material at 10%. MDD 2.182 gm/cm3 and OMC 8.4, similarly, at 20%, MDD 2.105 gm/cm3 and OMC 11.4% and at 30%, MDD 2.103 gm/cm3 and OMC 11.4%

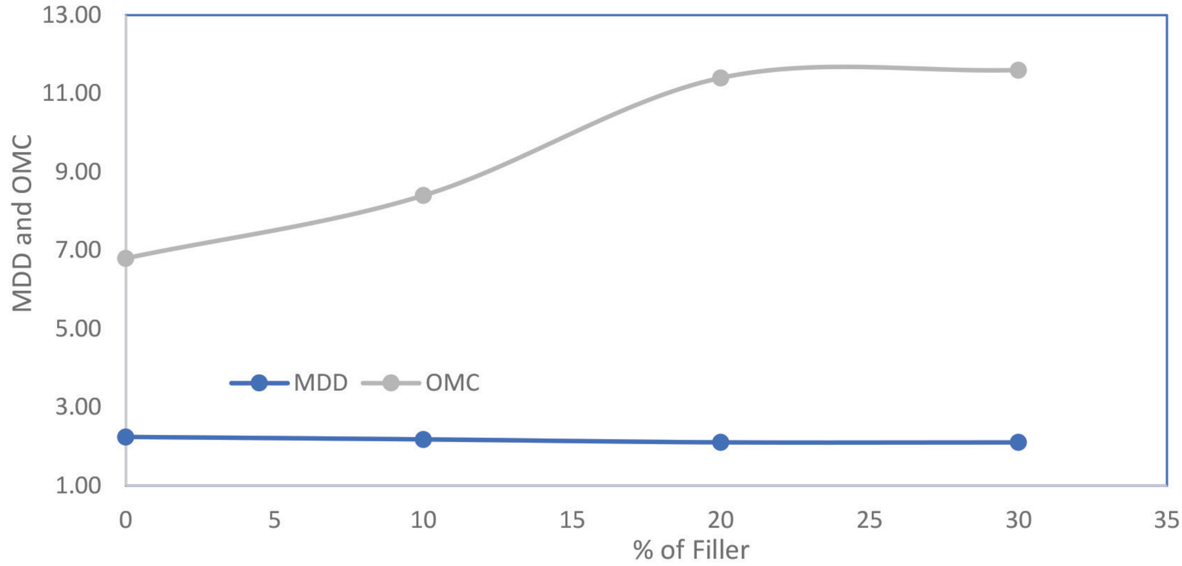

Fig. 7: Variation on MDD and OMC as the filler increase on riverbed sub base sample.

As the filler increase the MDD is reduced by 6.28% at 30% filler addition similarly 70.58% OMC increase at 30% filler addition. This variation shows due to the 23% OMC of filler sample. On the basis of gradation sub base sample have to add 10% soil sample filler.

California Bearing Ratio (CBR)

CBR requirement is vital for the performance and durability of the road. It certifies that the sub base layer can resist the stresses and strains imposed by traffic loads, preventing extreme distortion and maintaining the integrity of the road structure. The CBR test is a crucial part of geotechnical investigation during the design and construction of roads.

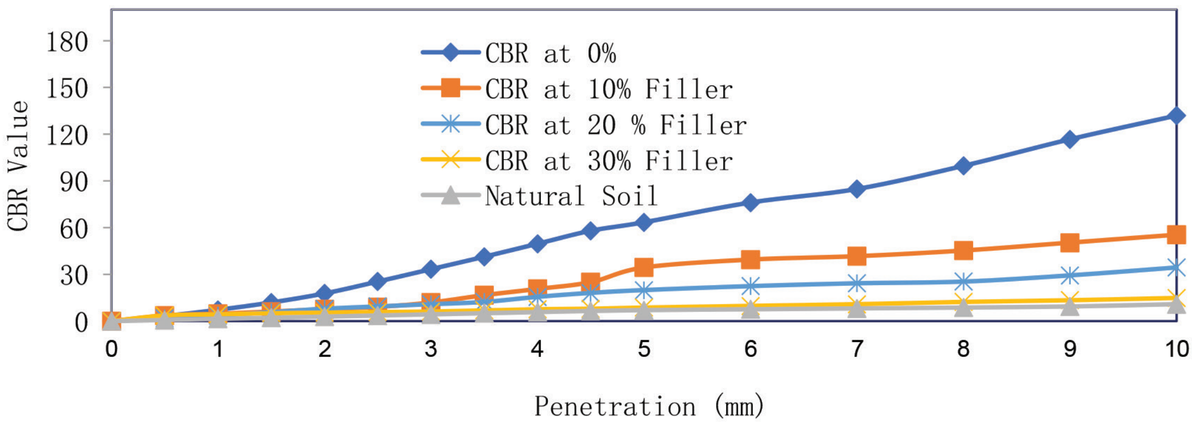

Fig. 8: CBR value with and without addition filler material on sub base sample.

CBR values for sub base indicate its quality. CBR value is taken at 2.5mm & 5 mm penetration for road construction. CBR value should not be less than 30% for sub base layer as per Department of Road Standard Specification for Road and Bridge-2078 ((with second amendment 2078) of Department of Road (DoR), Nepal. From the above graph CBR without addition of filler is 60.28% and addition of filler CBR reduces to 31.167%, 18.045% and 7.874 % on addition of filler sample 10%, 20% and 30% respectively.

4. Conclusions

The addition of filler soil helps in achieving the desired gradation in the sub-base material. Gradation is crucial for the proper performance of road materials, affecting factors such as drainage and stability. The plastic index decreases as the filler soil is added. This reduction is likely beneficial, as a lower plastic index indicates a decrease in the clayey and plastic nature of the soil. This can contribute to improved strength and stability. The addition of filler soil with low specific gravity to high specific gravity sub-base material results in a decrease in the overall specific gravity. This change could have implications for the overall weight and density of the sub-base. The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) decrease with the addition of filler soil. CBR value also decrease as the addition of soil as filler, but beyond 10% addition of filler decrease CBR as define in specification. This suggests that the modified sub-base mix achieves better compaction at lower moisture content, which is often desirable for road construction.

The addition of filler has a significant impact on both the compaction characteristics (MDD) and moisture requirements (OMC) of the material. The variation in OMC is explained by the inherent moisture content of the filler material. Additionally, the gradation analysis suggests a specific percentage of soil sample filler is needed for the sub-base material. These findings are important considerations in construction and geotechnical engineering to ensure the desired properties of the material are achieved. The addition of filler soil appears to positively impact the sub-base material's gradation, plasticity, specific gravity, compaction and CBR characteristics. These improvements are crucial for ensuring the long-term performance and stability of road construction projects. On the addition of 10% filler soil sample on river bed sub base also meet at the requirement as define by standard specification for road and bridge.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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