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Evaluation of Engineering Properties of the Rapati Nadi Aggregates for Railway Ballast in the Central Nepal Sub-Himalaya

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Abstract: Nepal has proposed various railway projects, such as the East-West Railway, Kathmandu Metro Railway, and Raxaul-Kathmandu Railway. Good ballasts are always sought in the projects to diminish maintenance cost. Sediments from the Rapati Nadi (River) in central Nepal are among probable sources of ballasts as those sediments are rich in quartzite clasts. To meet the ballast requirements for railway projects, the study assessed the physical, mechanical and durability properties of alluvial deposit aggregates.

The compositional analysis yielded maximum percentage of quartzite followed by sandstone and others. The aggregates yielded uniformity in gradation. Flakiness and Elongation Indices of the tested samples ranged from 11.18 to 24.10% and from 13.07 to 42.77%, respectively. Specific gravity exceeded 2.4. Aggregate Impact Value, Aggregate Crushing Value and Los Angeles Value of the tested samples were respectively 4.4-13.2%, 10.20-17.67% and 15.75-34.25%. Similarly, the point load strength index ranged from 3.69 to 6.57 MPa, and the Sodium Sulphate Soundness Values ranged from 0.96 to 2.06%. All the test results satisfied the conditions based on IS specification in the context of aggregate shape, crushing strength, impact strength, and durability against abrasion. When the results of different indices and values are rated based on their higher, intermediate and lower ranges, all the samples fall in the range of the high rating. Thus, it shows suitability of aggregates of the Rapati Nadi and sediment aggregates deposited between Basantapur and Bastipur seem better compared to other locations.

Keywords: ***Railway ballast, Rapati Nadi sediments, Central Nepal, Sub-Himalaya.***

Introduction

Railway transportation is one of the fastest and most efficient land transport systems. The track consists of rails and sleepers supported by ballast, which provides drainage, load distribution, and stability (Robnett et al., 1975; Mishra et al., 2013). Ballast is composed of medium- to coarse-grained aggregates (10–60 mm) with minor cobble-sized particles (Chrismer, 1985; Indraratna, 2006). Its quality depends on rock type, size, shape, strength, and durability, with hard rocks like granite, basalt, and quartzite preferred over weaker varieties such as slate or schist (Raymond, 2006).

In Nepal, ongoing projects such as the East-West and Raxaul-Kathmandu Railways demand large quantities of durable ballast. The quartzite-rich alluvial deposits of the Rapati Nadi may serve as a potential source. This study evaluates the physical and mechanical properties of Rapati Nadi aggregates and their suitability for railway ballast based on Indian Standard specifications.

Location

The study area lies along the Rapati Nadi between Bastipur and Basantapur in Makawanpur District, Central Nepal. It falls within the Sub-Himalayan Zone and features rugged hilly terrain with elevations ranging from 310 m at Basantapur to 940 m at Sanobhawar. Major tributaries include Chakari, Makari, Thado, Masine, Twanra, Darai, Bhotu, Badh and Chanura Khola, which flow northward to join the Rapati Nadi.

Geological setting

The Rapati Nadi watershed lies in the Lesser Himalayan and Siwalik zones (DMG 2020). Lesser Himalayan rocks include sandstone, schist, phyllite, quartzite, and marble of the Lakharpata and Bhimphedi Subgroups, while the Siwalik Group comprises fluvial mudstone, sandstone, and conglomerate with a coarsening-upward succession (Tamrakar 2002). Quaternary river and terrace deposits consist of rounded to sub-rounded cobbles and gravel, mainly quartzite and sandstone, transported by north-flowing tributaries.

Methodology

Twelve aggregate samples were collected from river bars and terrace deposits of the Rapati Nadi at ~1 km intervals using shallow pits. Their engineering properties were evaluated following IS specifications, including gradation, flakiness and elongation, specific gravity, density, water absorption, impact and crushing values, point load strength, Los Angeles abrasion, and sodium sulfate soundness and compared with American, European, and Australian standards to assess

mechanical strength, durability, and suitability as railway ballast.

Results and discussion

The study area along the 12 km stretches of Rapati Nadi (Bastipur–Basantapur) comprises Lower Siwalik Subgroup and Quaternary deposits. About 82% of the samples have smooth texture, 78% are rounded, and major cobble composition is quartzite (≈75%) and sandstone, with minor amounts of granite, phyllite, schist, marble, slate, gneiss, and limestone. Aggregates of desired size (19.5-63 mm) ranged from 26.7-48.5%, while >63 mm material can be crushed for ballast.

Most aggregates are smooth, rounded, and predominantly quartzite, resulting in favorable Flakiness (11.18-24.10%) and Elongation Indices (13.07-42.77%). Specific gravity, water absorption (0.48-2.26%), and strength indices, (point load 3.69-6.57 MPa, ACV 10.20-17.67%, AIV 4.4-13.2%) indicate high mechanical performance. Durability tests (LAAV 15.75-34.25%, SSSV 0.96–2.06%) show good resistance to abrasion and weathering. Overall, the results indicate that the aggregates are suitable for railway ballast.

Comparison of test result with American, European and Australian Standard

The aggregates were compared with American Standard, European, and Australian standards. According to ASTM, most samples meet Flakiness, Elongation, water absorption, LAAV, and SSSV limits, except a few outliers. European standards show that Flakiness is acceptable, but some elongation and LAAV values exceed limits. Australian standards are largely satisfied, with all samples meeting ACV and LAAV limits; only one sample slightly exceeds the Elongation Index limit. Overall, most aggregates conform to international specifications for railway ballast.

Evaluation among the samples from twelve locations

The result of engineering properties of aggregate was rated to assess overall quality, classifying samples into low, medium or high categories. All samples fall in the high-quality range, indicating good workability, strength and durability. Among locations, Basantapur and Rajaiya rank highest, while upstream samples (Masine-Bastipur) and Dardara are comparatively lower. This ranking highlights the Basantapur-Bastipur stretch as the most promising source for railway ballast.

Conclusions

Aggregates from the Rapati Nadi demonstrate excellent strength and durability characteristics, meeting standard specifications for railway ballast. The quartzite-dominated deposits, particularly between Basantapur and Bastipur, represent a reliable and high-quality source for future railway infrastructure development in Nepal.

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