Aggregate Properties Of Fluvial Deposits Of Malir, Lyari And Hub Rivers Of Karachi Embayment, Southern Indus Basin, Pakistan

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DOI: 10.29322/IJSRP.12.07.2022.p12706
http://dx.doi.org/10.29322/IJSRP.12.07.2022.p12706

Paper Received Date: 8th June 2022
Paper Acceptance Date: 25th June 2022
Paper Publication Date: 6th July 2022

Abstract- Karachi Embayment is a part of southern Indus Basin, which is located in the south of Sindh province of Pakistan. Fluvial deposits in Karachi Embayment are a major source of crushed fine and coarse aggregate for use in concrete in Karachi city. Therefore, engineering properties (physical and mechanical) of Hub, Malir and Lyari Rivers natural coarse aggregate were determined. In addition, comparison between these properties have been made. Nine samples (three samples from each river) were carefully collected and tested to evaluate engineering properties. The results of overall aggregate properties pointed out that Hub, Malir and Lyari rivers natural coarse aggregate is within the international (ASTM) standard values limits and it is suitable for use in concrete. In addition, by the comparison of laboratory testing of the various samples of Hub, Malir and Lyari Rivers indicates that aggregate of Hub River deposits has superior mechanical and physical properties in comparison with other aggregate of Malir and Lyari rivers deposits hence are potentially suitable for many special concrete purposes.

Index Terms- Aggregate, ASTM, Fluvial deposits, Karachi Embayment, Specific gravity test, Concrete, Laboratory Testing, soundness test, Water absorption test.

I. INTRODUCTION

The Karachi Embayment is located in the southernmost portion of Sindh and Lower Indus Basin, lies between latitude 66º35'00"-67º30'00" E and longitude 24º45'00" to 25º05'00" N (Figure 1). The Karachi region is home of a broad range of landforms with various nature and origins. The landscape assemblage depicts a fascinating and convoluted denudational timeline. (Saeed et al. 2017) mentioned that "Coastal part of Sindh lies in the seismically active zone" (Tatheer and Yasmeen, 2012). In terms of geology, Karachi region represents sedimentary rocks of late tertiary which are overlain by fluviate and aeolian sediments of Quaternary age (Shah, 1977). The landscapes of the study area give evidence of structural and lithological control. However, aeolian sandy/silty sediments covers much of the ground surface like a blanket, and gravely mounds of varying proportions are visible as relics of ancient river terraces in several locations. The relief condition of the land, in general, demonstrates maturity. The Malir River and Lyari River are the main streams draining Karachi region (Figure 2). The liquefaction potential is affected by the earthquake's intensity, magnitude, duration of ground motion, distance from the epicenter, site-specific conditions, ground acceleration, type and thickness of soil deposits, relative density, grain size distribution, fine contents, plasticity of fines, degree of saturation, confining pressure, permeability of soil layer, position and fluctuation of ground water table, reduction of effective stress, and shear modulus. (Youd and Perkins, 1978; Tuttle et al., 1999; Youd et al., 2001). The Karachi region presents the landforms of varied nature and origin ranging from the arid to fluvial and marine landscapes. This assemblage of landscape reflects polygenesis in origin. Structurally the whole region of Karachi presents a series of plunging folds trending NE-SW which is name after the localities as Cape Monze, Pir Mangho, Drigh road and Landhi-Korangi anticlines. These four anticlines are alternated with three synclines named as Laljee, Lyari and Malir synclines which are traversed by these sizeable seasonal streams (Hamid et al., 2019).

Malir River (MR). Lyari River (LR) and Korangi Conglomerate (KG) on the down side of the probable Malir River fault (MR). This is perhaps part of a fault zone (thick wavy red line) that forms this tectonic boundary which

runs west to east from the SW tip of this map to Thatta and beyond. Right lateral movement and drag along this tectonic boundary caused by eastward creep of Karachi Arc (red arrow) (Sarwar et al., 2013).

Karachi's uneven plain tract is made up of two alluvial-filled valleys, the basins of the brief Lyari and Malir rivers. The earlier synclinal lows are reflected by these two valleys, which are flattened by the fluvial deposits (coarse river gravels and calcareous sand). The Hub River Basin, to the west, presents very comparable characteristics like the basins of Malir and Lyari Rivers. The thickness of fluvial sediments exceeds 30 feet in most dug water wells in Karachi's central area.

The main purpose of our study is to evaluate the mechanical properties and comparison of the fluvial deposits of the three ephemeral Malir, Lyari and Hub Rivers in the Karachi Embayment as coarse aggregates for the construction purpose. We completed our field work in 7 days, we made the traverses along the bank of the rivers which were highly exposed by fluvial deposits. We used GPS, Brunton compass, geological hammer sample bags and safety equipment for data collection during the field work.

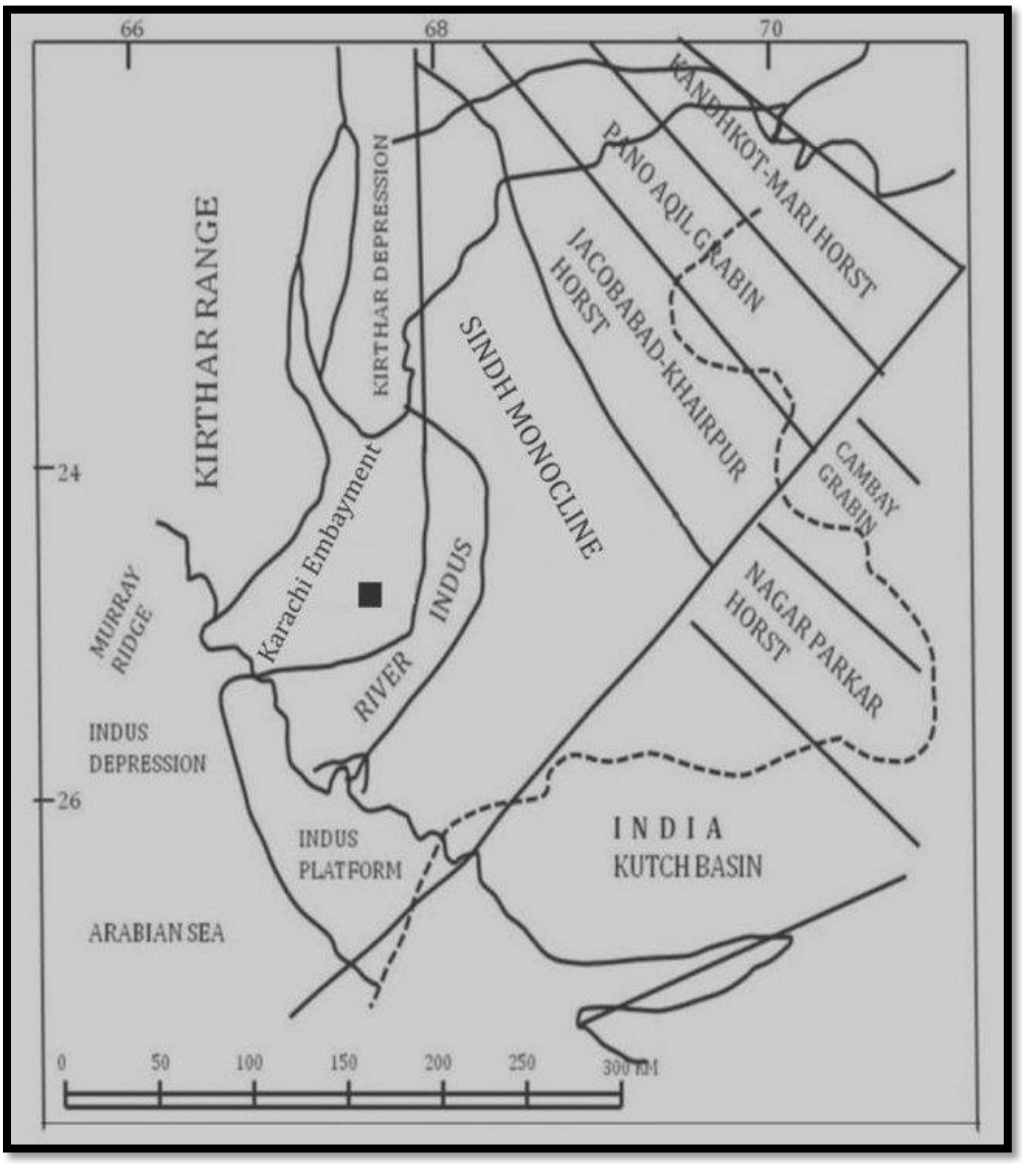

Figure 1. Tectonic map of Sindh (Southern Indus Basin), rectangle shows study area (Modified after Kazmi and Rana 1982; Raza et al, 1990). Karachi Embayment is an interesting feature as it is embayment opening up into Arabian sea.

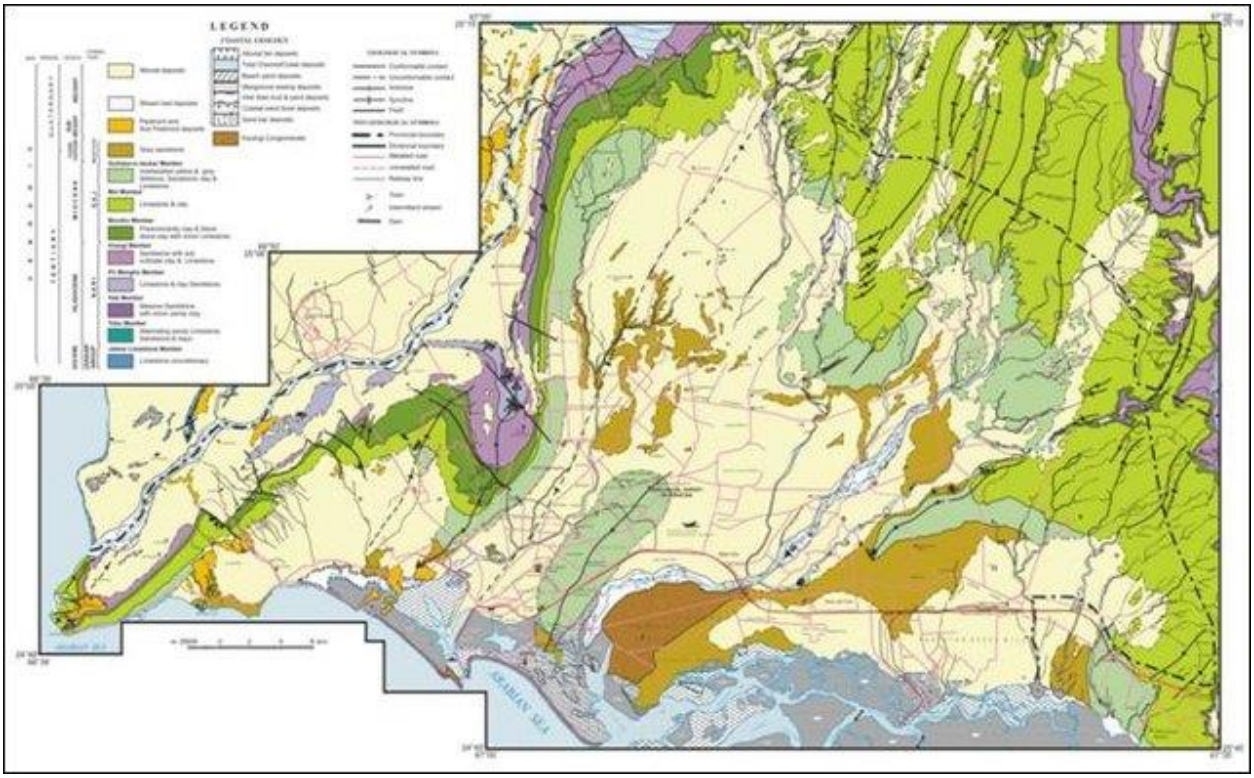

Figure 2. Showing the Geology of the Karachi Embayment (after Qureshi et al. 2001).

1.1. Stratigraphy

The stratigraphy of the study area ranges from Eocene Kirthar Formation to Pleistocene Dada Formation (Shah 1977) (Table 1).

Table 1: Stratigraphic sequence of the project area. (Fatima A N Stratigraphy of Pakistan Shah S.M.I (1977).

Formation	Age	Description
Dada Formation	Pleistocene	Mainly consists of gravels, loosely cemented sand and silt matrix. Upper part is covered by sub recent to recent fluvial deposits (rock fragments, conglomerate, sand, silt and clay).
Manchar Formation	Pliocene	Consists of sandstone which is thickly bedded and massive, grey and greenish grey color, soft friable, coarse grained interconnected with sandy clay. Sandstone suggests the shallow water deposition environment and there is an unconformity between Manchar formation and Dada formation.
Gaj Formation	Miocene	Consists of three members which are Metan clay (greyish to brown, soft to moderate hard) in lower part, Jhill limestone (hard thin bedded light brown to cream colored, massive and nodular), and Talawa limestone (brown color, hard, thin to thick bedded) in the upper part.
Nari Formation	Oligocene	Consists of limestone (dark brown, nodular, thin to medium bedded, silicious and fossiliferous) in lower part, sandstone and shale (greenish to grey) in the upper part.
Kirthar Formation	Eocene	Dominantly consists of dark grey, golden brown, or light grey color limestone.

1.2. Geology and Tectonic Setting of the Study Area

The geological structural setup of Karachi region belongs to the Southern Indian Basin which is a result of the rifting during Triassic and oblique collision of the Indo-Pakistan plate with the Afghan blocks during the Late-Cretaceous, and by post collision deformation during Neogene and Quaternary periods. Tectonically the counter clockwise movement of Indian plate during Eocene time, after its collision with Eurasian plate, has resulted in the formation of Karachi Embayment. It has remained as a trough in the recent geological time. It was followed by structural deformation in the late Pleistocene to middle Pleistocene related to the Himalayan Orogeny (Bender and Raza, 1995). Structurally, the city of Karachi lies approximately 150 km east of the triple junction between the Arabian, Indian, and Asian plates (Apel et al. 2006). A thrust and fold belt extending northward parallel to transform fault separating India from Asia, and the Kuch fault system trending westward toward the city. Karachi is a part of a major synclinorium stretching from Ranpathani River in the east to Mehar and Mol Jabals in the north and sea coast in the south (Hamid et al,.2019). Karachi is situated on or close to four minor faults. The first is the Allah Bund fault, which runs through the seaside village of Shah Bundar, the region around Pakistan Steel Mills, and through the city's eastern sections, finishing near Cape Monz. Another fault may be seen near Sindh's southeastern border with India, in the Rann of Kutch. The Pubb fault, located near the Makran coast west of Karachi, is the third, while the Dadu fault, located on the city's northern border, is the fourth (Bender and Raza 1995). The Karachi region is structurally part of Lower Indus Basin's Kirthar fold belt, which consists of series of plunging folds that make trend from NE-SW. Four large anticlines name Cape Monze, Pir Mangho, Drigh road and Landhi-Korangi anticlines with three intervening Laljee, Lyari and Malir synclines structures are shown in cross section from West to East direction. Synclinal troughs are alluvial-filled basins that connect three stream drainage networks (Figure 3).

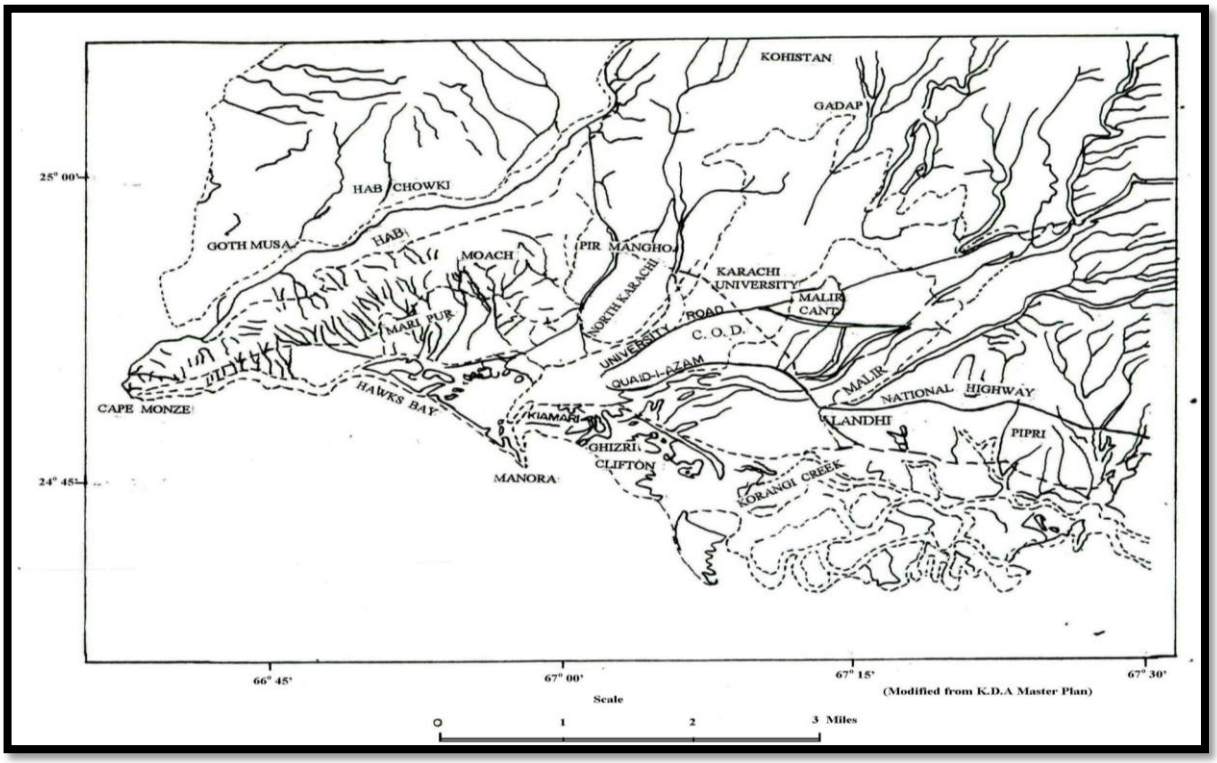

Figure 3. Shows the drainage pattern of the study area. (Modified after K.D.A Master Plan).

1.3. Climate

Karachi has an arid climate; however, it is a mild form of it. As a result of its location on the Arabian Sea's shore, it has a comparatively warm climate.

Summer and winter are the two primary seasons of Karachi, with spring and fall being brief. The summer season lasts the longest during the year. Karachi is also rained on from July to September (Monsoon). The city has a tropical climate, with mild winters and scorching summers. The humidity levels are normally high from March to November,

but are relatively low in the winter due to the north-east wind direction. In the winter, the temperature drops below 10°C on occasion, with a daytime temperature of around 25°C (Figure 4).

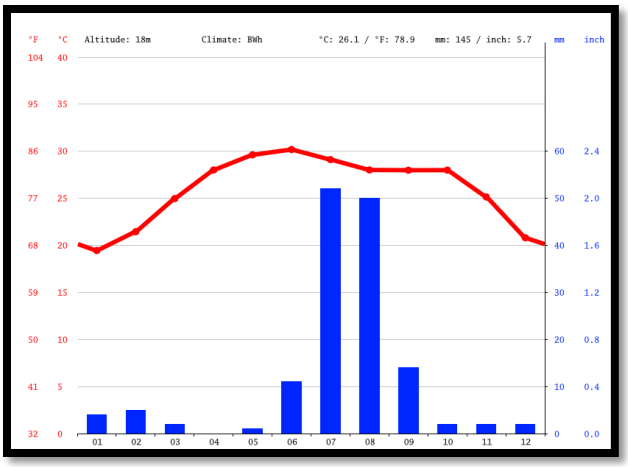

Figure 4. Show the Average Weather, Temperature of Karachi (Climate-data.org)

1.4. Location and Accessibility

The location marks by GPS, Brunton compass. Various locations were marked at the sampling points, like Memon Goth, Rais Goth, near Khan Crusher, Goth Band Murad on the banks of the three rivers. The sampling of Lyari River accessible by Lyari Express,

1.5. Objective

To investigate the mechanical characteristics of Fluvial deposits of Hub, Malir and Lyari Rivers and compare them to ASTM standards using aggregate testing.

II. Methodology

2.1. Selection of Sampling Site

Choosing a sample site is a technical procedure that takes place during field operations. The samples are taken from a location that is both conveniently accessible and well outcropped. To determine the mechanical properties of a samples, they were chosen. The texture, structure, size, and form of the samples were all taken into consideration while choosing them. For identifying position and dip strike, we used a Brunton compass, and for collecting samples, we used a geological hammer with proper safety. Field date samples are analyzed in the lab after they are collected.

III. Results

3.1. Los Angeles Abrasion Test (ASTM C 131)

Los Angeles Abrasion resistance test carried out to indicate crushing, degradation, disintegration and toughness of aggregates. Principally, this test produces abrasive action on aggregates by using standard steel balls in revolving hollow cylinder of Los Angles Abrasion resistance testing machine to determine the percentage weathering of aggregates. The machine contains a hollow cylinder closed at one end having a diameter of 700 mm and a length of 500 mm. In this cylinder 5kg of aggregates are filled with the steel balls of size 40mm & weight 390- 445kg each. After mixing the cylinder is allowed to rotate with the speed of 30-33 RPM with total of 500-1000 revolutions as selected by category. the sample is removed and washed over a No. 12 (1.70mm) sieve and placed in an oven to dry and the percent loss or the difference between the original mass and the final mass is calculated with the help of formula, weight of aggregate pass through 1.7 mm sieve divided by total weight of sample multiply by 100 we can get the percentage value for Los Angles Abrasion resistance values of aggregates (Table 2, 3 and 4).

Table 2: Shows Los Angeles Abrasion Resistance Test values after lab-testing of samples Hub River collected from study area.

S/ N	Sample	Coordinates	Dry Weight (g)	Retain Weight (g)	Loss Weight (g)	Abrasion Value	A/ V Average value	ASTM standard value
1	KCHR-01	N 25 01 38 E 66 56 47	5000	4100	900	18%	*18.1 %*	>60%
2	GBMHR-02	N 25 05 33 E 67 00 07	5000	4120	880	17.6%		
3	RGHR-03	N 25 00 45 E 66 53 21	5000	4065	935	18.7%		

Table 3: Shows Los Angeles Abrasion Resistance Test values after lab-testing of samples Malir River collected from study area.

S/ N	Sample	Coordinates	Dry Weight (g)	Retain Weight (g)	Loss Weight (g)	Abrasion Value	A/ V Average value	ASTM standard value
1	IGMR-01	N 24 54 25 E 67 15 53	5000	3820	1180	23.6%	*24.8 %*	>60%
2	GMR-02	N 24 53 23 E 67 14 13	5000	3700	1300	26%		
3	MGMR-03	N 24 54 07 E 67 15 28	5000	3765	1235	24.7%		

Table 4: Shows Los Angeles Abrasion Resistance Test values after lab-testing of samples Lyari River collected from study area.

S/ N	Sample	Coordinates	Dry Weight (g)	Retain Weight (g)	Loss Weight (g)	Abrasion Value	A/ V Average value	ASTM standard value
1	ISLR-01	N 24 55 41 E 67 05 13	5000	3980	1020	20.4%	*19.4 %*	>60%
2	HSLR-02	N 24 53 49 E 67 03 11	5000	4060	940	18.8%		
3	PPLR-03	N 33 40 981 E 73 38	5000	4050	950	19%		

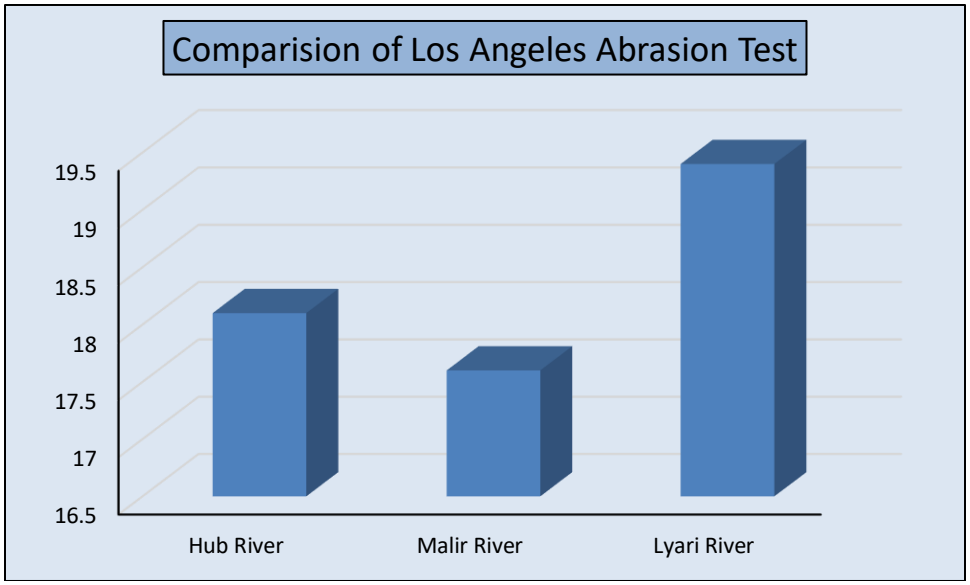

Figure 5. Comparison of Los Angeles Abrasion test results of samples collected from Hub, Malir and Lyari river.

3.2. Soundness Test (ASTM C 88)

Aggregate test samples were carefully sorted and weighed before being soaked in a sodium sulphate or magnesium sulphate solution and oven dried under certain conditions. The formation of salt crystals in the test sample's pores is thought to cause disruptive internal forces comparable to those produced by water freezing or salt crystallization. The weight reduction is calculated after a certain number of cycles.

When evaluated with sodium sulphate and magnesium sulphate, the average weight loss after 10 cycles should not exceed 12 percent and 18 percent, respectively.

Table 5: Shows Soundness Test values after lab-testing of samples Hub River collected from study area.

S/ N	Sample	Coordinates	Dry Weight (g)	Retain Weight (g)	Loss Weight (g)	Abrasion Value	A/ V Average value	ASTM standard value
1	KCHR-01	N 25 01 38 E 66 56 47	5800	5570	230	3.96%	*3.96%*	12%-18%
2	GBMHR-02	N 25 05 33 E 67 00 07	5800	5571	229	3.94%		
3	RGHR-03	N 25 00 45 E 66 53 21	5800	5567	233	0.4%		

Table 6: Shows Soundness Test values after lab-testing of samples Malir River collected from study area.

S/ N	Sample	Coordinates	Dry Weight (g)	Retain Weight (g)	Loss Weight (g)	Abrasion Value	A/ V Average value	ASTM standard value
1	IGMR-01	N 24 54 25 E 67 15 53	5800	5341	459	7.91%	*7.8 %*	12%-18%
2	JGMR-02	N 24 53 23 E 67 14 13	5800	5550	450	7.75%		
3	MGMR-03	N 24 54 07 E 67 15 28	5800	5367	433	7.74%		

Table 7: Shows Soundness Test values after lab-testing of samples Lyari River collected from study area.

S/ N	Sample	Coordinates	Dry Weight (g)	Retain Weight (g)	Loss Weight (g)	Abrasion Value	A/ V Average value	ASTM standard value
1	ISLR-01	N 33 58 260 E73 83 186	5800	5484	316	5.4%	*5.1 %*	12%-18%
2	HSLR-02	N 33 45 337 E 73 42 511	5800	5500	300	5.1%		
3	PPLR-03	N 33 40 981 E 73 38	5800	5517	283	4.8%		

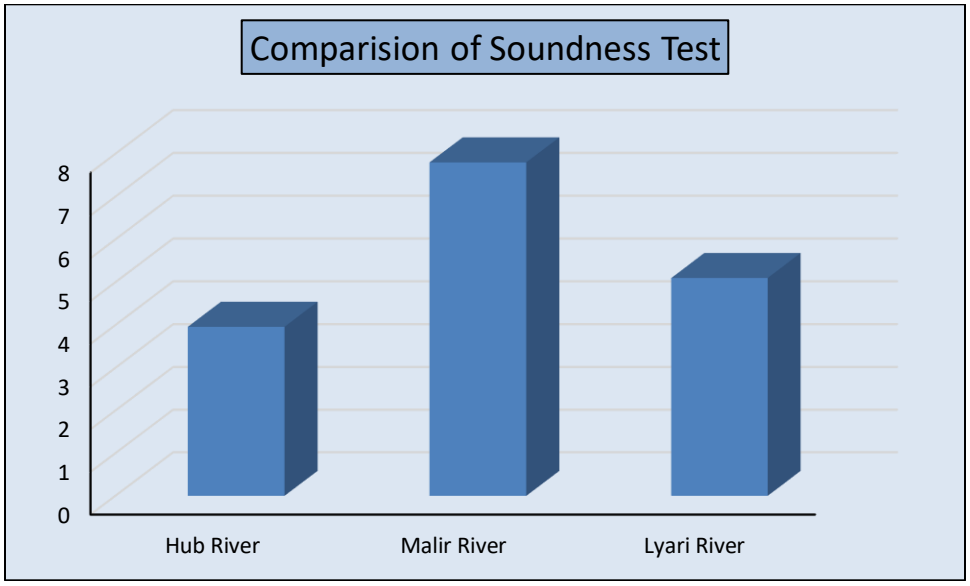

Figure 6. Comparison of Soundness test results of samples collected from Hub, Malir and Lyari river

3.3. Aggregate Crushing Value Test (ASTM D 5821)

Aggregate crushing value test on coarse aggregates gives a relative measure of the resistance of an aggregate crushing under gradually applied compressive load. In this method coarse aggregate passing 12.5mm IS sieve and retained on a10mm IS sieve are selected and heated at 100 to 110°C for 4 hours and cooled to room temperature. The quantity of aggregate shall be such that the depth of material in the cylinder, after tamping as described below shall be 10 cm. Put the cylinder in position on the base plate and weigh it **(W)**, put the sample in 3 layers, each layer being subjected to 25 strokes using the tamping rod, and weigh it **(W1)**. Level the surface of aggregate carefully and insert the plunger, place the cylinder with plunger on the loading platform of the compression testing machine. Apply load at a uniform rate so that a total load of 40T is applied in 10 minutes. Release the load and remove the material from the cylinder. Sieve the material with 2.36mm IS sieve, care being taken to avoid loss of fines. Weigh the fraction

passing through the IS sieve **(W2)**. W2 =Weight of fraction passing through the appropriate sieve W1-W =Weight of surface dry sample. The mean of two result to nearest whole number is the aggregate crushing value.

Table 8: Represents the Aggregates Crushing Values after Lab- testing of samples from Hub River collected from study area.

S/ N	Sample	Coordinate s	Present value	Average value	ASTM standard value
1	KCHR-01	N 25 01 38 E 66 56 47	20%	*20%*	10-30%
2	GBMHR-02	N 25 05 33 E 67 00	19.8%		
3	KHKS-03	07 N 25 00 45 E 66 53 21	20.4%		

Table 9: Represents the Aggregates Crushing Values after Lab- testing of samples from Malir River collected from study area.

S/ N	Sample	Coordinate s	Present value	Average value	ASTM standard value
1	IGMR-01	N 24 54 25 E 67 15 53	20.9%	*20.4%*	10-30%
2	JGMR-02	N 24 53 23 E 67 14	20.2%		
3	KHKS-03	N 24 54 07 E 67 15 28	20%		

Table 10: Represents the Aggregates Crushing Values after Lab- testing of samples from Lyari River collected from study area.

S/ N	Sample	Coordinate s	Present value	Average value	ASTM standard value
1	ISLR-01	N 33 58 260 E 73 83 186	24.2%	*23 %*	10-30%
2	HSLR-02	N 33 61 034 E 73 77 983	22.7%		
3	KHKS-03	N 33 38 376 E 73 44 734	21.9%		

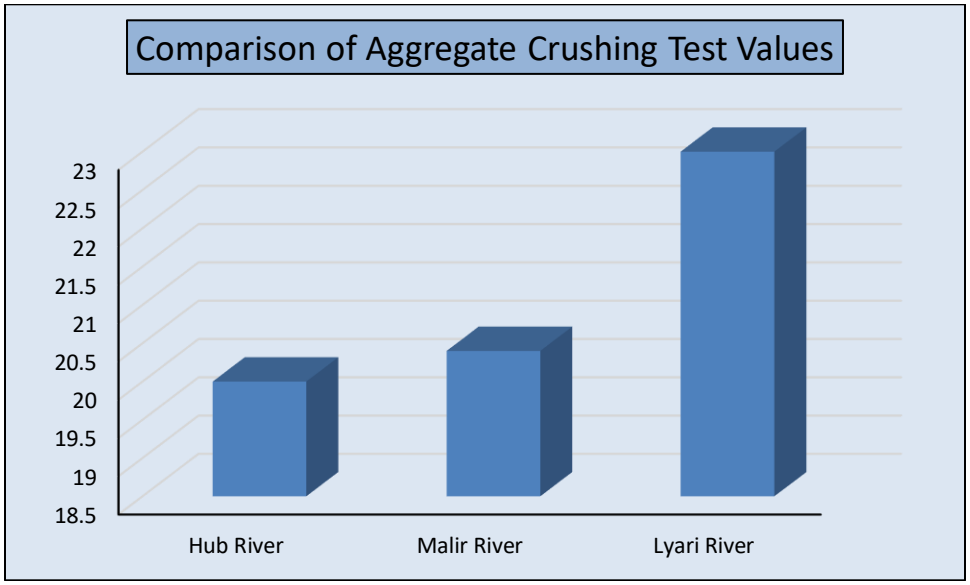

Figure 7. Comparison of Aggregate Crushing Value test results of samples collected from Hub, Malir and Lyari river.

3.4. Water Absorption Test (ASTM D 570)

The purpose of **ASTM D570** is to determine the rate of absorption of water by immersing the specimen in water for a specific period of time. The formula B-A divided by A is used to calculate Water Absorption values, where B is the saturated surface dry weight of the sample after submerge in water for 24 hours and A is the sample's oven dry weight. The average water absorption value from the test findings was 2.24, which is greater than the ASTM (American Society of Testing and Materials) standard range of 0.1-1.0 or 0.6 per unit weight. The period of immersion, the temperature of the water, the thickness of the sample, and the kind of sample are the important elements to consider while doing this test.

Table 11: Shows the values from Lab- Data for the Water. Absorption Test of Hub River samples collected from study area.

S. N	Sample Name	Water Absorption values	Mean values	Standard value for water absorption
1	KCHR-01	1.9%	*1.95*	Less than 0.6 per unit by weight
2	GBMHR-02	2%		
3	RGHR-03	1.96		

Table 12: Shows the values from Lab- Data for the Water. Absorption Test of Malir River samples collected from study area.

S. N	Sample Name	Water Absorption values	Mean values	Standard value for water absorption
1	IGMR-01	2%	*1.86*	Less than 0.6 per unit by weight
2	JGMR-02	1.6%		
3	MGMR-03	2%		

Table 13: Shows the values from Lab- Data for the Water. Absorption Test of Lyari River samples collected from study area.

S. N	Sample Name	Water Absorption values	Mean values	Standard value for water absorption
1	ISLR-01	2%	*2.13*	Less than 0.6 per unit by weight
2	HSLR-02	2.4%		
3	PPLR-03	2%		

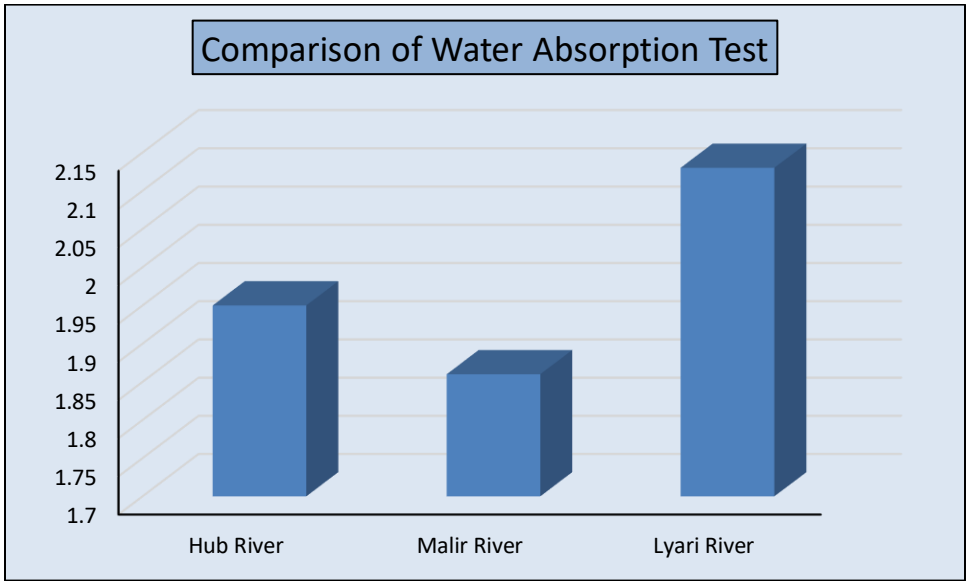

Figure 8. Comparison of Water Absorption test results of samples collected from Hub, Malir and Lyari river.

3.5. Specific Gravity Test

Table 14: Shows the values of Specific Gravity values from Lab-Data for Hub River collected from study area.

S. N	Sample Name	Coordinates	O. Dry Wt. (g)	O. Dry Wt. (g)	App S.G.	Mean Value	ASTM standard value
1	KCHR-01	N 25 01 38 E 66 56 47	1000	380	2.63	*2.6*	2.6 - 3.0
2	GBMHR-02	N 25 05 33 E 67 00 07	1000	389	2.57		
3	RGHR-03	N 25 00 45 E 66 53 21	1000	382	2.61		

Table 15: Shows the values of Specific Gravity values from Lab-Data for Malir River collected from study area.

S. N	Sample Name	Coordinates	O. Dry Wt. (g)	Wt. in Water (g)	App S.G.	Mean Value	ASTM standard value
1	IGMR-01	N 24 54 25 E 67 15 53	1000	390	2.56	*2.56*	2.6 - 3.0
2	DMGMR-02	N 24 53 23 E 67 14 13	1000	388	2.57		
3	MGMR-03	N 24 54 07 E 67 15 28	1000	391	2.55		

Table 16: Shows the values of Specific Gravity values from Lab-Data for Lyari River collected from study area.

S. N	Sample Name	Coordinates	O. Dry Wt. (g)	Wt. in Water (g)	App S.G.	Mean Value	ASTM standard value
1	ISLR-01	N 33 61 034 E 73 77 983	1000	382	2.6	*2.62*	2.6 - 3.0
2	HSLR-02	N 33 38 376 E 73 44 734	1000	380	2.63		
3	PPLR-03	N 33 45 337 E 511	1000	380	2.63		

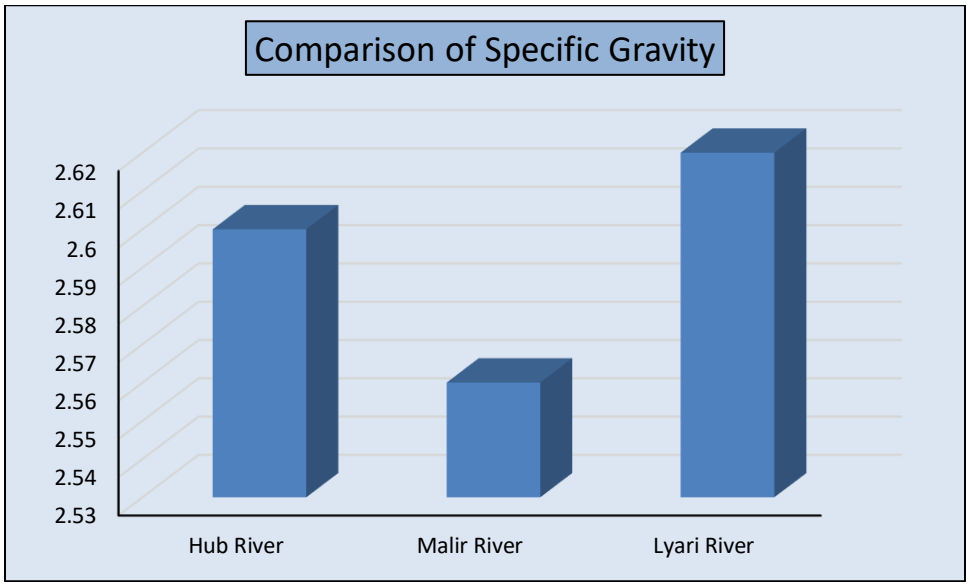

Figure 9. Comparison of Specific Gravity test results of samples collected from Hub, Malir and Lyari river.

IV. Discussion

The evaluation of mechanical properties, determined by analyzing the resulting values of the tests like Los Angeles abrasion resistance, Aggregate Crushing Value, Soundness, Water Absorption and Specific gravity. 9 samples were collected from the banks of the three rivers (three samples from each river) to conclude the, Los Angles Abrasion resistance values, Aggregate crushing values, Soundness test values, Water absorption and Specific gravity values of the coarse aggregate to examine its mechanical properties to be use in the construction industry, and on the basis of mechanical properties, to compare the aggregates of Hub, Malir and Lyari rivers. The average resulted abrasion values of Hub River samples is 18.1 percent loss (table 17) indicates very satisfied condition, and the other two Malir River and Lyari River having good resulted values of 24.8 percent loss (table 17) and 19.4 percent loss (table 17) respectively which are also giving a satisfied condition and can be used as coarse aggregate for construction purpose as the ASTM standard value is for coarse aggregate is less than 60% of loss. If we talk about Aggregate Crushing values, the ACV of Hub River is 20 percent (table 17) which is less than the other two Malir and Lyari rivers crushing values. The ASTM standard value for ACV lies between 10-30% and the results of ACV of all the samples lies in 10-30% which provide a satisfied condition. The resulting values of Soundness test of all the samples are also lies in the standard ASTM values. Likewise, Water Absorption values from results as an average of 1.95 (table 11) percent, 1.86 percent (table 12) and 2.13 percent (table 13) that are considerably bigger than to the ASTM standard value i.e., 0.1-1.0 or 0.6 per unit weight. The values obtained don't qualifying ASTM absorption values. And the mean specific gravity results are 2.6 (table 14), 2.56 (table 15) and 2.62 (table 16) for Hub, Malir and Lyari rivers respectively which may be between 2.6-3.0.

Table 17: Shows the comparison between Aggregate Crushing Values and Los Angles Abrasion resistance test values from Lab- Data of the samples of Hub, Malir and Lyari Rivers, collected from study area.

S/N	Sample	Avg. Abrasion Values	Avg. Crushing Values	Avg. Soundness Test Values
1	Hub River	18.1%	20%	3.96%
2	Malir River	24.8%	20.4%	7.85%
3	Lyari River	19.4%	23%	5.1%

V. Conclusion

After doing the evaluation of mechanical properties of the coarse aggregate samples of three rivers and their comparison, we concluded that aggregate of the Hub River is comparatively best than the aggregate of other two rivers for the construction purpose. After Hub River we can consider the aggregate of Lyari River as better aggregate, and aggregate of Malir River is also good for the

construction purpose. We also concluded that the resulting values of all the aggregate samples are the standard ASTM values of their mechanical properties which indicates that fluvial deposits of the rivers of Karachi can use as aggregate for construction purpose.

Acknowledgement

Department of Geology, Karachi University is highly acknowledged for providing the lab facility to perform practical work.

Conflict of Interests

Authors declares no conflict of interests over the manuscript.

Funding

This research receives no funding.

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