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Flood Sediment Characterization and Modification as Construction Material

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Abstract. Flood affected the south Indian state, Kerala in 2018 monsoon and has suffered unprecedented losses as evidenced by damage to physical infrastructure especially roads and bridges. The rebuilding of these infrastructures needs thousands of crores of money and millions of cubic meters of construction materials. Kerala state faces a problem of deficiency in natural resources for rebuilding its infrastructure. Reuse of immense quantity of flood sediment can be a better solution for rebuilding activities. Characterization of flood sediments deposited on the banks of water bodies and its suitability in construction activities were studied. This paper describes the studies conducted on flood sediment at Pandalam region (Pampa River Basin). Particle gradation of the samples collected showed that with modification, it can be used as masonry sand. Pandalam sediment was mixed with various percentage (10 to 50 %) of sand particles passing through 600 µm and retained on 300 µm IS sieves. Sieve analysis and zonation of fine aggregate prepared by the above method were carried out. Fine aggregate obtained by a combination of 60 % Pandalam sediment and 40 % of additive sand particles satisfied all the IS specifications required for masonry and plastering mortar. Hence the modified Pandalam sediment can be used as an alternative to the fine aggregates in masonry and plastering mortars. Sustainable utilization of sediments can cut down the use of conventional fine aggregates such as river sand and M-sand.

Keywords: Flood sediments; gradation; fine aggregate.

1 Introduction

Flood is nothing but the overflow of water that inundates the land that is usually dry. Along with the flowing water, they bring along ample debris and eroded soil from the surrounding landscape. As the water flow slows down these eroded materials that are transported by water, settles out of water column onto the surface. Large quantities of flood sediments get settle after each flood event. These sediments consist of mud, sand, soft clay, consolidated clay, organic matter, plastic…etc mixed up.

Due to the unusually high rainfall during 2018 monsoon season, severe flood affected Kerala. In nearly 100 years, it was the worst flood, affected Kerala since 1924.

Millions of tonnes of sand and mud were brought in by the floodwaters and deposited on roads, bridge, riversides and public places. From a preliminary assessment, it was found that 2.5 lakh cubic meters of sand had been deposited at the Pampa Manalpuram and surrounding areas itself. Revenue Department had quantified the quantum of sand deposit at 1.29 lakh cubic meters, while Irrigation Department quantified it at 75,000 cubic meters [1]. Sometimes large quantity of these materials are kept unutilized on the place of deposition itself. Due to the absence of proper characterization and associated studies these sediments are usually treated as waste materials and are removed by non-government agencies at a cheap rate. The fig.1 shows the dredging of flood sediments and associated sediment removal activities at the Pampa- Triveni in the foothills of Shabarimala.

Fig. 1. Dredging of flood Sediments and Removal Activities at the Pampa- Triveni [1]

The Post Disaster Need Assessment (PDNA) commissioned by the Government of Kerala after the flood, estimated the total disaster effects of around INR 26,720 crore without including the damage estimates from the Joint Rapid Damage and Needs Assessment (JRDNA) conducted by the World Bank and the Asian Development Bank (ADB). By including the recovery needs estimated by JRDNA, total recovery needs are estimated as INR 31,000 crore (USD 4.4 billion). Among the main sectors, infrastructure sectors have highest recovery needs (51% of the total recovery needs) [2].

The rebuilding of these infrastructures needs thousands of crores of money and millions of cubic meters of construction materials. Kerala state faces a problem of deficiency in natural resources for rebuilding its infrastructure. Hence reuse of immense quantity of flood sediment can be a better solution for rebuilding activities. Sustainable utilization of flood sediments helps in reducing environmental impact as well as act as a resource for construction materials and source of income to the authorities.

2 Investigations on Flood Sediment Characterization and Possibility of its Reuse as Fine Aggregate in Mortars

To achieve beneficial use of sediments in construction field, accurate assessment and characterization of sediments is essential. To define sediments' physical, chemical and geotechnical properties, standard and reliable evaluation techniques are required. These properties are essential for the selection of appropriate use of sediments. In India currently there are no formal standards available for the purpose. In countries like Ireland also no such standards are available to characterize dredged marine sediments. But they use some international guidelines such as CEFAS (2002) and OSPAR (2009)[3]. Hence test procedures and specifications can be adopted from Indian standard codes for the characterization of flood sediments [4].

Generally, to satisfy the rapid infrastructure growth, the demand of river sand is high in developing countries. Due to this, sand is becoming very costly and the situation demands a very cheap and easily available substitute material. Many researches have started with a vision of developing a sustainable practice for the beneficial use of industrial wastes or natural wastes such as dredged sediments [5]. Dredged materials, a natural waste were used in brick manufacturing, road construction and in mortar and concrete [6].

Similarly, sustainable utilization of un-utilized flood sediments may cut down the depletion of valuable construction materials which is of natural origin such as river sand, M-sand, soil, clay for building blocks manufacturing...etc. If we use the flood sediment, it would enhance both economy and environment. To use this sediment as a replacement for natural sand or M-sand in cement composites such as cement mortar and cement concrete, it is important to work out the characteristics of these composites with flood sediment, prior to its use in practical applications.

On both the mechanical and rheological properties of mortars and concrete, aggregates have a significant influence. Shape, surface texture, specific gravity and particle size distribution of aggregates influences the properties of concrete and mortar in the fresh state. On the otherhand elastic modulus, toughness, mineralogical composition and degree of alteration of aggregates affects the properties of concrete and mortar in the hardened state [7]. Further, comparing to the coarse aggregate, particle size distribution of the fine aggregate was found to have a greater influence in the properties of concrete. As a result, choice of appropriate type of fine aggregate is important as far as properties of mortars and concrete are concerned

The ratio of mix we choose in different situation depends on the intended use. For example, load bearing structures such as foundations require a higher sand to cement ratio than non-load bearing structures. For general purposes, cement mortar of ratio 1:6 is used. For heavy duty projects, 1:4 and 1:3 mixes are used. But to test the suitability any fine aggregate as an ingredient in mortar, a mix of 1:6 is used for the compressive strength test as per IS:2116 (for masonry mortar) and IS:1542 (for plastering mortar).

3 Experimental Studies

3.1 Materials used

The flood sediment samples used for the study was collected from a point near the Pandalam Valiya Koyikkal Dharmasastha Temple, Pathanamthitta district, Kerala, which is on the banks of Achankovil River. Collected approximately 50 kg of the sediment from a depth of 1m from the ground surface. Fig. 2 shows the gradation curve of the Sediment. Sediment is even finer than the sand conforming to grading zone IV. OPC 53 grade cement was used for the experimental program. The properties of cement are given in Table 1.

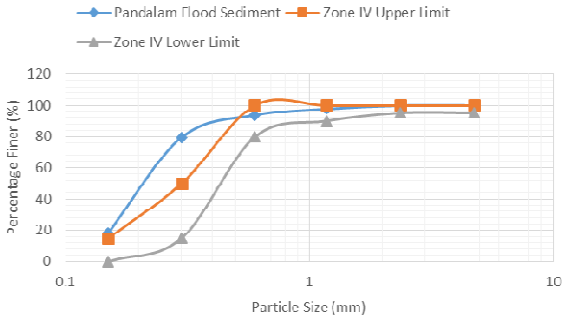


Fig. 2. Gradation Curve of Insitu Pandalam Flood Sediment

Table 1. Properties of Cement

Properties	Values
Specific gravity	3.1
Standard consistency (%)	32
7^{th} day compressive strength (N/mm^2)	38
28^{th} day compressive strength (N/mm^2)	54

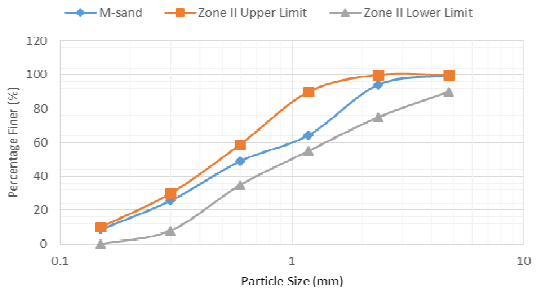


Fig. 3. Gradation Curve of Collected M-Sand

Manufactured sand (M-sand) used for the test was collected from the Structural Engineering Laboratory, College of Engineering Trivandrum. Fig. 3 shows the gradation curve of the collected M-sand. M-sand was used as fine aggregate in preparation of control mortar mix. The properties of M-sand are given in Table 2

Table 2. Properties of M-sand.

Properties	Values
Specific gravity	2.72
Bulk density (g/cm^3)	1.69
Void ratio	0.38
Porosity (%)	27.5
Fineness modulus	2.59
Moisture content at maximum bulking (%)	8
Percentage of maximum bulking (%)	43

3.2 Methodology

In order to characterize the sediment various laboratory tests were carried out on the insitu sediment for obtaining it's physical, chemical and geotechnical properties. The tests were done in accordance with the Indian Standard (IS) codes. To make the sediment lie within the limits of sands for mortars, coarser M-sand particles (size less than 600 micron and greater than 300 micron) were added at 10%, 20%, 30%, 40% and 50%. After arriving within the gradation limits, different tests such as soundness test, clay lump determination test and organic impurity determination test were done on modified flood sediment. Compressive strength test were done on mortar cubes made of it. Control M-sand which is in the same grading zone as that of modified sediment is prepared and the results were compared. The results were also compared with the minimum requirements as per the IS Codes.

4 Characterization of Flood Sediment

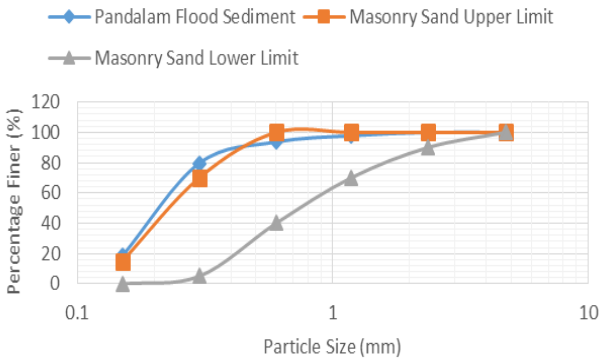
4.1 Physical, chemical and geotechnical characterization

The physical characteristics of flood sediments are important indicators of its engineering properties and any potential environmental impacts. The in-situ water content, specific gravity, fineness modulus and colour of flood sediment was determined. The XRF test was used to determine the chemical constituents of sediment. The P^H of the sediment was determined in accordance with the IS 2720 (Part XXVI). Loss on ignition (LOI) does not have a universally accepted standard protocol. Crucible along with sediment was kept in a muffle furnace at a temperature of 400^{o}C for 3 hours [8]. After 3 hours, it took out and kept for some times to achieve room temperature. Ratio of loss of weight on ignition to the weight of soil gives the LOI value. The organic carbon content of the sediment was determined in accordance with IS 2720 (Part

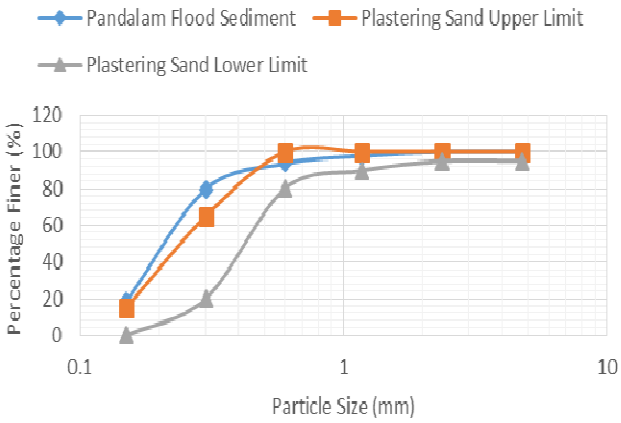
XXII). The tests for geotechnical characterization includes wet sieve analysis, hydrometer analysis, standard proctor compaction and California Bearing Ratio test.

5 Modification of Flood Sediment

Collected flood sediment is very fine to be used in any concrete or mortar constructions. Hence it can't be used as such. As per IS 383, to use a fine aggregate in concrete or masonry preparation, it should conform to any one of the four grading zone limits. From the fig 4, it is clear that insitu sediment lies outside the required limits of sand for masonry and plastering mortar.



(a)



(b)

Fig. 4. Gradation Curve of In-situ Sediment in the Limits of (a) Sand for Masonry Mortar (b) Sand for Plastering Mortar

Comparing to the other grading zones, zone IV is easily achievable with less addition of coarser particles. Percentage finer value corresponding to the particle size 0.3 mm (or 300 micron) is the main point which lies outside the upper limits of grading zone IV. So, if we could reduce the percentage of material passing through 300 microns sieve, we can bring the gradation curve within the limits. Hence M-sand particles whose size less than 600 micron and greater than 300 microns were sieved out. The insitu sediment was replaced by these M-sand particles at different percentages – 10%, 20%, 30%, 40% and 50%. The gradation curve of the sediments at different replacement levels of M-sand particles are shown in fig. 5. Addition of 40% of M-sand particle whose size is less than 600 micron and greater than 300 microns could bring the gradation within the limits of grading zone IV.

In order to compare the properties of modified sediment and the mortars prepared with it, a control M-sand which is conforming to the same grading zone (zone IV) was prepared. Gradation curve of control M-sand prepared is given in Fig. 6(a). Fig.6(b) shows the Control M-sand in the limits of sand for mortars.

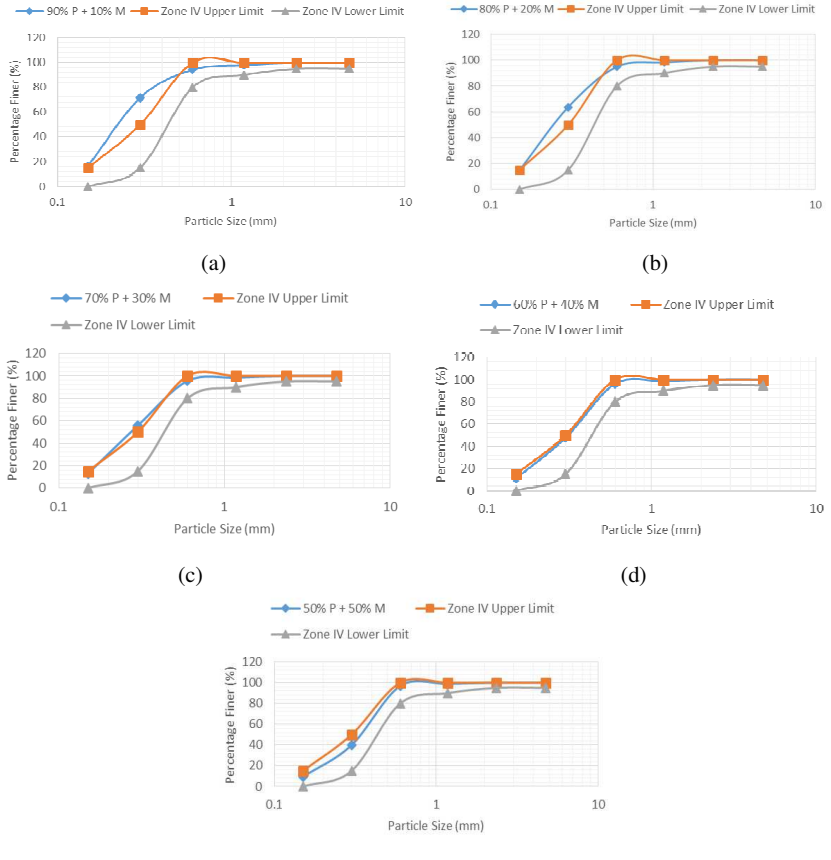
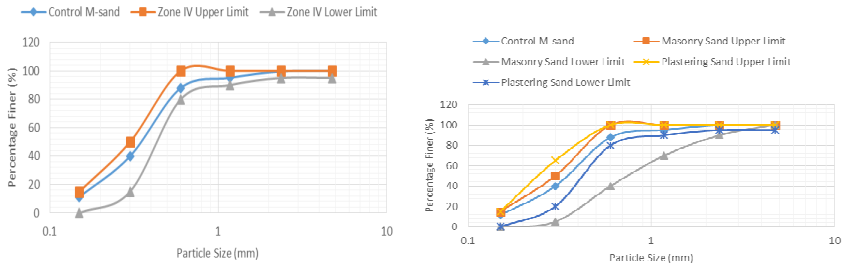


Fig. 5. Sediment Modification with Different Replacement Level of M-sand Particles (a) 10% M-sand Particles (b) 20% M-sand Particles (c) 30% M-sand Particles (d) 40% M-sand Particles (e) 50% M-sand Par-



(a) (b)

Fig.6. Control M-sand (a)In the Limits of Grading Zone 4 (b)In the Limits of Sand for Masonry and Plastering

6 Results and Discussion

6.1 Characterization of flood sediment

Table 3 shows the physical properties of insitu Pandalam flood sediment. The fineness modulus value of 1.1 shows that collected sediment is finer than the normally used fine sand in concrete production.

Table 3. Physical Properties of Pandalam Flood Sediment

Properties	Values
In-situ water content (%)	29.76
Specific gravity	2.68
Fineness modulus	1.1
Colour	Pale Brown

Table 4. Chemical Properties of Pandalam Flood Sediment

Properties	Values
Silica (%)	86.15
Alumina (%)	5.38
Magnesium Oxide (%)	1.02
Iron Oxide (%)	1.48
Calcium Oxide (%)	2.81
Sulphuric Anhydride (%)	0.01
Loss on ignition (%)	4.54
P^H	7.27
Organic carbon content (%)	0.86

Table 5. Geotechnical Properties of Pandalam Flood Sediment

Properties	Values
Percentage of gravel (%)	0
Percentage of sand (%)	82.36
Percentage fines (%)	17.64
Percentage of silt (%)	9.2
Percentage of clay (%)	8.44
Soil classification	Fine sand
Optimum moisture content (%)	16.31
Maximum dry density (g/cc)	1.64
Unsoaked CBR (%)	9.8

A time series survey conducted in 2002 reports that P^H of water in Achankovil River is in the range of 6.32 to 7.56 [9]. Hence it is clear that a time gap of 16 years or flood event in 2018 didn't contaminate the soil much. Table 4 and table 5 shows the chemical properties and geotechnical properties of insitu sediment.

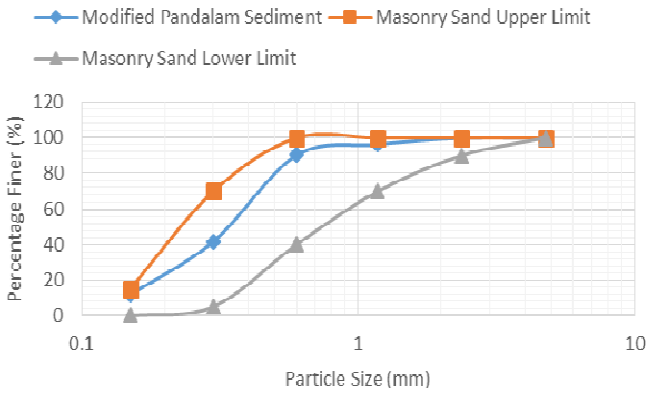
6.2 Suitability of modified Pandalam sediment as fine aggregate in masonry mortar and plastering mortar

Less specific gravity value of modified sediment may be due to presence of higher organic matter compared to control M-sand. Higher soundness value of modified Pandalam flood sediment indicates its susceptibility to weathering action. Table 6 shows the general requirements of fine aggregates to be used in concrete or masonry.

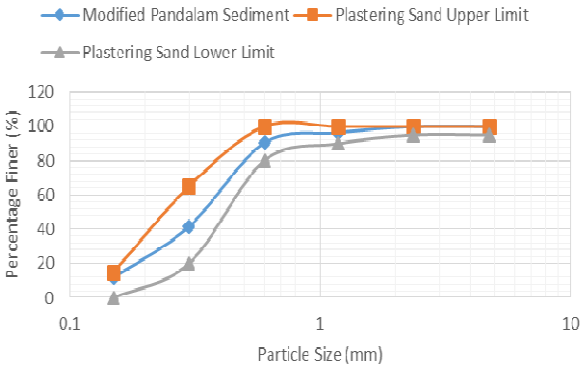
Table 6. General Requirements of Fine Aggregates

Sl. No.	Characteristics	Test as per standard	Control M-sand	Modified Pandalam sediment	Require-ment	Require-ment as per standard
1	Specific gravity	IS 2720-1963 (Part 3)	2.73	2.70	-	-
2	Soundness by using Na_2SO_4 – 5cycles (%)	IS 2386-1963 (Part 3)	5.69	9.58	Max. 10%	IS 383-2016

Fig. 7 shows gradation curve of modified sediment (with addition of 40% of M-sand particles whose size less than 600 micron and greater than 300 micron) in the limits of sand for masonry mortar and plastering mortar. Hence gradation wise, Pandalam sediment can be utilized effectively by modifying it.



(a)



(b)

Fig.7. Modified Pandalam Sediment (a)In the Limits of Sand for Masonry Mortar(b)In the Limits of Sand for Plastering Mortar

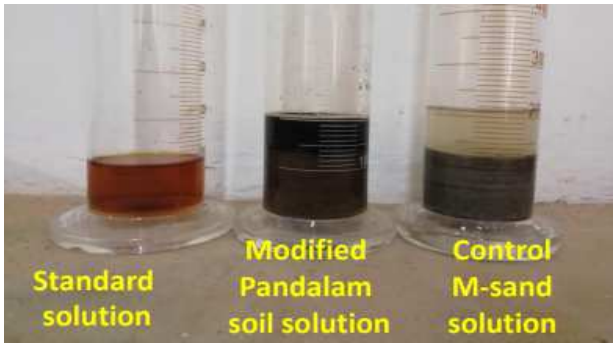


Fig. 8. Results of Organic Impurity Determination Test

(a) (b)

Fig. 9. Fracture pattern of mortar cubes (a) Using modified Pandalm sediment (b) Using control M-sand

Table 7. Requirements of Fine Aggregate for Masonry Mortar

Sl. No.	Characteristics	Test as per standard	Control M-sand	Modified Pandalam sediment	Require-ment	Require-ment as per stan-dard
1	Particle size distribution	IS 2386-1963 (Part 1)	Within limits	Within limits	Should be within upper and lower limits	IS 2116-1980
2	Clay lumps (%)	IS 2386-1963 (Part 2)	1.1	19.2	Max. 5%	IS 2116-1980
3	Organic impurities	IS 2386-1963 (Part 2)	Lighter	Darker	Colour of liquid should be lighter than standard solution	IS 2116-1980
4	Compressive strength at 28^{th} day - 1:6 mix (N/mm^2)	IS 2250-1981	6.5	5.5	3 to 5 N/mm^2	IS 2250-1981

For modified sediment, the obtained value of clay lumps is 19.2, which is very much higher. As per IS 2116 and IS 1542 specifications, for both mortar sands and plastering sands, the colour of the liquid after organic impurity determination test should be lighter than that of standard solution. Fig. 8 shows the results of organic impurity

determination test. Figure indicates that modified Pandalam flood sediment contains more organic matter than that is allowed. Suitable pretreatment such as washing can be adopted to remove the deleterious materials such as clay lumps and organic impurities. Compressive strength value obtained for the modified flood sediment is 5.5 N/mm^2 which is greater than the minimum requirement. Fig. 9 shows the fracture pattern of the mortar cubes prepared using modified Pandalam sediment and control M-sand.

Higher soundness value and 'peel off' nature in crack pattern indicates that modified sediment is more suitable as masonry sand than plastering sand. From all these, the results can be tabulated as shown below. Table 7 presents the requirements of fine aggregate for masonry mortar and table 8 presents requirements of fine aggregate for plastering mortar.

Table 8. Requirements of Fine Aggregate for Plastering Mortar

Sl. No.	Characteristics	Test as per standard	Control M-sand	Modified Pandalam sediment	Requirement	Requirement as per standard
1	Particle size distribution	IS 2386-1963 (Part 1)	Within limits	Within limits	Should be within upper and lower limits	IS 2116-1980
2	Fineness modulus	IS 2386-1963 (Part 1)	1.66	1.60	≥ 1.5– natural ≥ 1.4- crushed	IS 1542-1992
3	Clay lumps (%)	IS 2386-1963 (Part 2)	1.1	19.2	Max. 5%	IS 2116-1980
4	Organic impurities	IS 2386-1963 (Part 2)	Lighter	Darker	Colour of liquid should be lighter than standard solution	IS 2116-1980
5	Compressive strength at 28^{th} day - 1:6 mix (N/mm^2)	IS 2250-1981	6.5	5.5	≥ 3 N/mm^2	IS 2250-1981

7 Conclusions

The following conclusions were drawn from the present study

1. With addition of 40% of M-sand particles (which pass through 600µ IS sieve and retained on 300µ IS sieve), the flood sediment can be used as fine aggregate for both masonry and plastering mortar preparation.
2. With suitable pretreatment such as washing, modified sediment can be used for brick laying, plastering of internal walls, external walls and ceiling.
3. Due to higher soundness value, modified sediment is better for masonry mortar preparation than plastering mortar.

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