Effective Utilization of Herbocrete - A natural admixture in cement mortar to assess the strength properties

Dr. M.Vijaya Sekhar Reddy[1], K.Asha Latha[2], M.Madhuri[3], K.Sasi[4], C.Vidya Sagar[5]

[1]Head and Assistant Professor , Department of Civil Engineering ,Srikalahasteeswara Institute of Technology, Srikalahasti, Andhra Pradesh, India. E-mail: skitce.hod@gmail.com

[2,3,4,5]Lecturer, Department of Civil Engineering ,Srikalahasteeswara Institute of Technology, Srikalahasti, Andhra Pradesh, India.

***Abstract* – Cement has been used as the major construction material. Lime is arguably the world first true green and versatile building material. With the introduction of Portland cement during the nineteenth century the use of lime mortar in new constructions gradually declined, largely due to Portland's ease of use, quick setting and compressive strength. Lime posse's greater qualities such as stickiness, ease of applications, breathability, moisture resistance, natural antiseptic, self healing, durability, low thermal conductivity, incombustible, solar production, harmonious balance. The traditional lime binder offers greater durability but less strong compared to cement. Now-a-days various chemicals are used as admixture to improve the strength and performance of concrete. The cement and chemicals used in modern construction causes environmental pollution and its effect is significant. But a variety of plants and animal products used in traditional lime mortar not only improves the strength but also proves its durability for centuries. It also helps to retrieve the traditional concept of addition of admixture to concrete. By shifting ourselves to use such eco-friendly (natural) admixtures in mortar will lead the construction industry towards sustainable development. So, in this study an effort is made to improve the strength parameters of the cement mortar by using natural admixtures. The natural admixtures that are found to improve the strength are "Terminalia chebula" (kadukkai). The compressive strength of varying proportions of admixtures is found out by experimental study and the values are compared with the conventional cement mortar. The proportions of admixtures are varied from 2.5% 5% 7.5% 10% 12.5% and 15%. The results show that the admixtures improved the strength of the cement mortar. Terminalia chebula when added to cement mortar has no effect on workability but increases the compressive strength by 1.31 times of reference mortar.**

***Index Terms*— Terminalia chebula , Jaggery, Kadukkai,**

1. Introduction

Holmes Stafford (2002), Cement forms an integral part of the modern construction industry for past 100 years. Though cement mortar offers early strength, faster construction, it has number of disadvantages such as the environmental impacts during its manufacture, energy consumption during manufacture and behavior under seismic forces is under great question [1].

David S Mitchell (2007), Compared to modern structures, traditional structures in India can be adopted by the people of all generation since the fundamental nature of construction is always flexible and in tune with the rhythmic spatial forms to suit the taste of every generation. Indian traditional structures built with lime mortar, which are more than 4,000 years old like Mohanjo-Daro is still a heritage monument of Indian civilization. The traditional construction concepts will definitely provide inputs to supplement modern construction methods and this will pave a flexible way by extracting the essence from ancient texts and interpret it to suit modern constructions [2].

Palomo et al., (2003), In recent past, attempts are being made to enhance the strength parameters by addition of chemical admixtures in cement concrete, though it is performing well in all mechanical characteristics. But the long term durability of cement has not been ascertained since cement came into existence in the past century. Lime is exceptionally durable. Lime's durability is evident throughout the ages. Though its durability aspect of lime mortar is time tested, its strength criterion stands lower than the Portland cement [3].

Pritchett (2003), Lime allows the building to "breathe". Water can escape by evaporation, unlike cement where the only way the water can escape is by being absorbed into the bricks. Lime is soft and flexible. It allows the building to move without cracking and letting water in and thus "self healing". Lime is normally considerably cheaper to produce, needs much lower or even negligible capital inputs to get started. Lime is biodegradable and recyclable. Lime is burnt at a lower temperature than cement in the production process (900°C as opposed to 1300°C), therefore making lime production is not only more environmentally friendly but also more economic as well. Lime can also be produced on a small scale to supply a local market. This greatly reduces transportation cost [4].

Lauren B. Sickels-Taves (2005), The Ancient Egyptians were the first to use lime mortars. About 6,000 years ago, they used lime to plaster the pyramids at Giza. In addition, the Egyptians also incorporated various limes into their religious temples as well as their homes. The Greeks have enabled us to witness the beauty and incredible durability of true lime stuccos. Innovative Greek builders used these fine lime plasters in creating the Parthenon and many other classic structures that survive into the present day. Lime was used extensively throughout the Roman Empire. The builders during that time possessed a firm knowledge of lime's many beneficial features, as a mortar and as a decorative finishing material. As the Empire grew, the Romans influenced architecture and structures throughout the civilized world. Consequently, many more people learned to appreciate the benefits of lime and embraced it as a building material [5].

2. Literature Review

Lime is arguably the world first true green and versatile building material. The traditional lime binder offers greater durability but less strong compared to cement. The objective of the present study is to improve the strength parameters of lime using traditional herbs. Lime mortar prisms (mix proportion: 1:2 i.e., one part of lime to 2 parts of sand) were cast after 15 days of fermentation with traditional herbal extract [aqueous extract of Oonjalvalli (Cissus glauca Roxb), pananchikaai (Cochlospermum religiosum), kulamavu (Persea macrantha), Gallnut (Terminalia chebula) and palm jaggery (from Borassus flabellifer) and tested for its flexure, tension and compressive strengths. The lime mortar prism fermented with plain water was used as control. The transverse strength of herbal lime mortar (5% herbs) is 1.6 times greater than lime mortar fermented with plain water. Besides, there was an increase in the tensile strength by three folds, due to elastic nature of herbal lime mortar. The compressive strength is greatly enhanced up to 2.5 times on the addition of 5% herbs. This may be due to the fact that herbal extract enhanced the density of lime mortar by bringing the particles of lime mortar closer to each other, thereby producing a more compact mass. Traditional structures built with lime mortar, which are more than 4,000 years old like Mohanjo-Daro is still a heritage monument structure of Indian civilization. It is more appropriate to blend the traditional concept with modern structures. The present work may also help in reviving ancient monuments [6].

3. Materials And Methods

In this present investigation the following materials were used.

- Ordinary Portland cement (53 grade),
- Fine Aggregate (sand <425μ),
- Teminalia chebula (kadukkai)
- Jaggery

3.1 Cement

Ordinary Portland cement Ultratech OPC 53grade conforming to IS: 12269-1987 [7] was used in concrete.

3.2 Aggregates

Natural sand from Swarnamukhi River in Srikalahasti with specific gravity of 2.60 was used as fine aggregate conforming to zone- II of IS 383-1970 [8].

3.3 Terminalia Chebula (Kadukkai):

This is the locally available natural admixture. Generally the kadukkai is used in medicals. And in our ancestors have used various plants as admixture in construction for more than 10000 years to improve overall performance of the structure. Herbal admixture (kadukkai) will definitely improve the strength and durability of the mortar but at the same time it does not produce any harm to our environment. It's as an admixture and medicinary plant, this plant leaves powder can also be replaced partially with cement. Detail Experimental investigation is done in the laboratory to determine the optimum usage of these herbal products in cement mortar.

Table 1. Physical Properties of Kadukkai

Properties	Result
Total ash %	37.85
Acid insoluble ash %	31.55
Alcohol extract value %	3.58
Water extract value %	17.72
Bulk density	0.352 g/ml
Tapped density	0.512 g/ml

Table 2. Chemical properties of Kadukkai

Element	Result	Permissible limits
Iron %	18.03	-
Cadmium ppm	0.0064	0.3
Mercury ppm	0.00578	1
Arsenic ppm	0.0405	3
Lead ppm	0.2144	10

3.4 Jaggery:

Jaggery, a product of sugarcane, is such a product which is rich in important minerals (viz Calcium, Magnesium, Potassium, Phosphorus, Sodium, Iron, Manganese, Zinc, Copper, Chloride). Jaggery is a natural traditional sweetener made by concentrating the extracted sugarcane juice. It contains all minerals in the sugarcane juice. This is the locally available natural admixture. Jaggery acts as a retarder and function of the retarder is to increase the setting time of the mortar.

Table 3. Composition of Jaggery

Minerals	**mg**
Calcium	40-100

Magnesium	70-90
Phosphorus	20-90
Sodium	19-30
Iron	10-13
Manganese	0.2-0.5
Zinc	0.2-0.4
Chloride	5.3-0
Copper	0.1-0.9

4. Methodology

The experimental investigation was carried out in seven different phases. The various phase involved have been explained as follows:

1. The first phase includes the collection of materials and preliminary investigation which were carried out on the constituents of the mortar.
2. The second phase involves the preparation of cement mortar. In this stage cement mortar was prepared by the adding water with the cement. This cement mortar is used for casting cubes.
3. The third phase includes the, fermentation of kadukkai and Jaggery. Fermentation of kadukkai is carried out by crushing and grinding of kadukkai and Jaggery is also crushing and allowed to be immersed in water for 7 days, 15 days and 28 days. Then the water in which kadukkai present is filtered and that water is added to the cement mortar.
4. In the fourth phase the cement mortar is prepared according to mix proportion and the workability of the mortar are found by flow table test as per Indian standard.
5. In the fifth phase the cube moulds were cast for mix proportions and combinations. The mortar were prepared and cast for ground conditions. The mortar cube was then allowed to cure by means of carbonation that is exposed to the sunlight and water curing for cement mortar.
6. Sixth phase involves the testing of the cast specimen for the workability test and compressive strength test.
7. And in seventh phase the experimental data was observed and analysed

4.1 Preparation of kadukkai extract

The kadukkai was crushed and ground. The ground kadukkai powder was mixed with suitable quantity of water and kept (fermented) in a closed container for 7 days, 15 days, 28 days separately. The kadukkai fermented are filtered after 7 days, 15 days, 28 days and the filtered water was used in the mortar mixes for different ratios. The mortar cubes is cast with the addition of kadukkai water was tested after 7 days, 15 days, 28 days of water curing.

Fig 1: Crushing of Kadukkai

Fig 2: Fermentation of Kadukkai

4.2 3.2 preparation of jaggery extract

The Jaggery was crushed on the ground. The crushed Jaggery was mixed with suitable quantity of water and kept (fermented) in a closed container for 7 days, 15 days, 28 days. The Jaggery fermented are filtered after 7 days, 15 days, 28 days. And the filtered water was used in the mortar mixes for different ratios. The mortar cubes is cast with addition of jaggery water was tested after 7 days, 15 days, 28 days of water curing.

Fig 3: Crushing of Jaggery

Fig 4: Fermentation of Jaggery

Fig 5: Jaggery Extract

MIX PROPORTIONING

The main aim of this research project is to utilize the natural admixtures Kadukkai and Jaggery in various dosages like 2.5%, 5%, 7.5%, 10%, 12.5%, 15% concentrations in mixing with water and increasing of admixture percentage to decrease the water content.

Trail 1=Conventional cement mortar.

Trail 2= 2.5% of Kadukkai and 2.5% of Jaggery extract to weight of water.

Trail 3= 5% of Kadukkai and 5% of Jaggery extract to weight of water.

Trail4 = 7.5% of Kadukkai and 7.5% of Jaggery extract to weight of water.

Trail 5 =10% of Kadukkai and 10% of Jaggery extract to weight of water.

Trail 6 =12.5% of Kadukkai and 12.5% of Jaggery extract to weight of water.

Trail 7 =15% of Kadukkai and 15% of Jaggery extract to weight of water.

Table 4. Mix Proportions of Mortar Trials

Trial no.	Weight of cement (kg)	Weight of fine aggregate (kg)	percentage of Kadukkai extract	percentage of Jaggery extract	No. of samples
T 1	2.5	7.5	-	-	9
T 2	2.5	7.5	2.5%	2.5%	9
T 3	2.5	7.5	5%	5%	9
T 4	2.5	7.5	7.5%	7.5%	9
T 5	2.5	7.5	10%	10%	9
T 6	2.5	7.5	12.5%	12.5%	9
T 7	2.5	7.5	15%	15%	9

5. Results

5.1 Workability Test:

The flow table test results were indicated in Table 5 and Figure 6.

Table 5 : Flow Table Results of Various Mortar Trail Mixes

S.No	Type of Motor	Flow Value
1	T1 (0%)	145
2	T2 (2.5%)	157
3	T3 (5%)	160
4	T4 (7.5%)	156
5	T5 (10%)	153
6	T6 (12.5%)	151
7	T7 (15%)	149

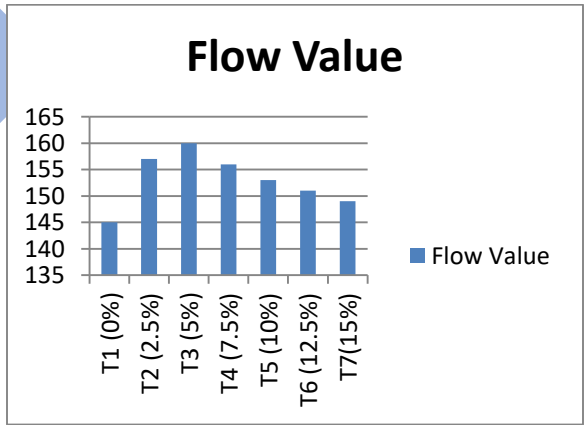

Fig 6: Flow Table Results of Cement Mortar

5.2 Compressive Strength:

The compressive strength of the different proportions is arrived and the results are compared with the reference cement mortar and listed in Table 6.

Table 6. Compressive Strength Results of Various Mortar Trail Mixes

S.No.	Trial Mix	Percentage of Kadukkai and	Compressive Strength (N/mm²)

		Jaggery extract	7 days	15 days	28 days
1.	T1	0%	15.08	18.7	20.9
2.	T2	2.5%	21.9	23.8	25.90
3.	T3	5%	23.05	25.3	27.50
4.	T4	7.5%	18.9	20.02	20.50
5.	T5	10%	17.09	18.3	19.06
6.	T6	12.5%	16.03	17.02	18.05
7.	T7	15%	14.12	15.07	17.02

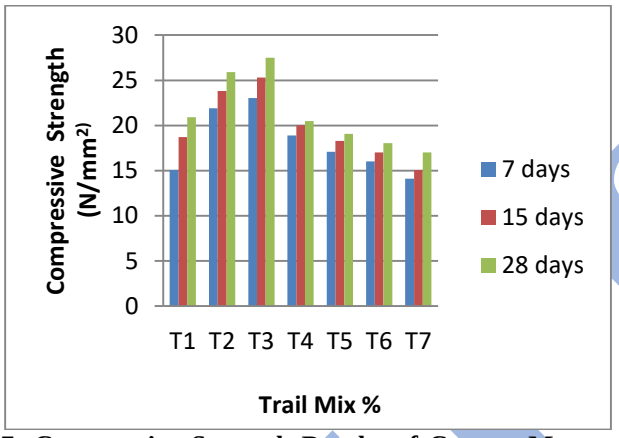

Fig 7: Compressive Strength Results of Cement Mortar For 7days, 15 Days and 28days

6. Conclusions

On the basis of results produced in this study it is concluded that:

- Addition of kadukkai increases the workability by 10%.
- The present experimental study reveals that the addition of natural admixture to the cement mortar will increase its compressive strength.
- The results shows that the maximum compressive strength for cement mortar is achieved with 5% of Kadukkai and Jaggery solution of water at 28 days is 27.5 N/mm^2.
- The compressive strength is increased by about 1.31 times of reference mortar for 28days fermentation of 5% of Terminalia chebula extract and Jaggery extract.
- The natural admixtures are environmentally friendly and they treated like pollution free admixture then compared to chemical admixture.

7. References:

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The combination of kadukkai (herbocrete) and jaggery solution along with lime was used in reconstruction of the heritage structure Srikalahasti Raja Gopuram and relevant photo copies are attached in this paper. This structure was built by Navayuga Engineering and Construction Company and Srikalahasteeswara Swamyvari Devasthanams.