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RESEARCH ARTICLE

FORMULATION AND PERFORMANCE CHARACTERIZATION OF CERAMIC TILE ADHESIVE PRODUCED WITH ACACIA GUM

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ABSTRACT

Redispersible polymer materials employed in the formulation of ceramic tile adhesives are products of high technology and are not easily available to the small scale producers of the adhesives. In this study, the potentialities of acacia gum as substitute for redispersible polymer material in ceramic tile adhesive was investigated. The adhesive samples were formulated using Portland cement, quartz sand, cellulose ether, calcium carbonate and acacia gum powder. The bond strength and mechanical properties of the adhesives were determined and compared with those of a popular commercial brand. The results revealed that after application, there was a general increase in bond strength, compressive strength, tensile strength and flexural strength of the adhesive samples over time. The formulated adhesive was comparable in performance to the commercial brand. This was evident in their mechanical properties in which the formulated adhesive and commercial brand had the following respective values of 11.48 KPa and 11.6 KPa for bond strength; 12.4 MPa and 12.8 MPa for compressive strength; 16.0 KPa and 16.4 KPa for tensile strength; 3.0MPa and 2.8MPa for flexural strength.

Key Words: Adhesive, Acacia Gum, Ceramic Tile Adhesive, Redispersible Polymer

INTRODUCTION

An adhesive is defined as any non-metallic material that is capable of joining bodies together by surface adhesion and internal strength without the structure of the bodies undergoing significant changes (Ulmann's, 1985). Ceramic tiling is commonly used these days in various application fields inside and outside buildings especially on floor and wall covering of building and swimming pools. The major materials involved in tiling are ceramic tiles, adhesive mortar (Bruno, 1970) and the substrate (floor or wall). In many modern construction applications, pure cement-based mortars without organic polymer binders are not able to meet the state-of-the-art technical requirements (Lutz *et al*., 2012). Even mortars that contain cellulose ether additives to improve water retention capability and thus curing of the cement, adhere poorly, or not at all, on many of the materials used in the modern construction industries like polystyrene, cement fibre and wood panels; as well as non-absorbent substrates like old tile surfaces and fully vitrified tiles (Lutz *et al*., 2012).

Furthermore, cement-based mortars are very hard, brittle and nonflexible material; and in many applications, flexible and deformable cement mortars are needed. Thus, the modification of cement-based mortars with polymers is, today, essential for many mortar applications (Lutz *et al*., 2013). Generally, the main components of a ceramic tile adhesive are cement (inorganic binder), mineral fillers, fine aggregates and organic additives, mainly cellulose ether and redispersible polymer powder (RPP). Cellulose ethers are part of the mortar formulation mostly due to workability reasons as they improve water retention, act as thickening agent and introduce air voids into the fresh mortar (Scharlemann *et al*., 2010; Paiva *et al*., 2006 and Baumann *et al*., 2010). They as well influence cement hydration, exhibiting a retarding effect on the drying of mortars (Silva and Monteiro, 2006). A typical formulation for ceramic tile adhesive according to Jenni *et al*. (2005) comprises ordinary Portland cement (35%), 425 - 500μm-size quartz sand (40%), calcium carbonate powder (22.5%), cellulose ether (0.5%) and redispersible polymer powder (2%) (Jenni *et al*., 2005). However, industrial formulations are usually more complex and contain additional components (Schulze and Kilermann, 2001). In a so-called two-binder system, the mineral binder (e.g. cement) and the polymer binder complement each other ideally.

Their combination results in outstanding synergistic properties and characteristics of the dry mortar, which cannot be produced by either of the two individual binders alone. When added to a dry mix mortar, they redisperse in water during mixing of the fresh mortar. In particular, the addition of RPP increases the consistency (Barluenga and Hernandez-Olivares, 2004), lowers compressive strength and E-modulus compared to a plain mortar with the same water/cement ratio, whereas the effect on the flexural strength seems to depend on the individual mix design and on the RPP chemical composition (Zhong and Chen, 2002 and Pascal *et al*., 2004). The simultaneous existence of binder and polymers provoke the interaction of the two fundamental processes: polymer film formation and cement hydration. Redispersible polymer materials further improve fresh mortar rheology, but mainly provide flexibility and tensile strength of the hardened mortar (Jenni *et al*., 2005). The powder is usually produced by spray drying of a polyvinyl alcohol (PVA) stabilized latex emulsion of the polymer. Materials commonly employed as redispersible polymer powder are: VC (vinyl-acetate/ethylene/vinyl chloride

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terpolymer), SA (styrene/acrylics copolymer), EVA (ethylene/vinyl acetate copolymer), VV (vinyl acetate/vinyl versatate/butyl acrylate terpolymer) and polyacrylic ester (Kaufman *et al.*, 2012). Production of RPP involves high technology and may not be available for small scale producers of ceramic tile adhesives; hence the need for locally sourced polymer materials which can be used as a substitute for RPP. Again, in view of global transition from the use of non-renewable (fossil-based) to renewable (plant-based) resource, there is need for development of environmental-friendly bio-materials in the adhesive industry as substitute for petroleum-derived products. Acacia gum (gum Arabic), the most abundant of all natural acacia exudates in Nigeria (Nuhu and Abdullahi, 2009), is a resin that contains arabin: a semi solid sticky fluid oozing from incision made on the bark of acacia tree. Nuhu and Abdulllahi reported that the trees grow more in Borno, Yobe, Sokoto and Bauchi states of Nigeria (Nuhu and Abdullahi, 2009).

Acacia gum has several uses which include the following. It is used in powdered form or in liquid for suspending sensitizer in hard coating on paper and masking agent in print. It is used in melting yarn chip processes to make yarn stronger and can be added to painting formula to fix pigment in fabrics. It acts as binder for pigments in watercolour, gouache paints, in aluminium plate process and adhesives for paper and liquid gum for general office purposes (Nuhu and Abdullahi, 2009). The physical and chemical properties of acacia gum are compatible with those required of sand binders in foundry. It was found useful as admixture in concrete mortar (Nuhu and Abdullahi, 2009). In view of the binding properties of acacia gum, it was used in this work as polymer binder in ceramic tile adhesive formulations.

MATERIALS AND METHODS

Materials

Cement: BURHAM cement was purchased from Ebonyi State Building Materials Market, Abakalik, Ebonyi state, Nigeria. It is an ordinary Portland cement that conforms to Nigerian standard with a Blaine specific surface area of 467.9m^2/kg, setting time of 75minutes, a specific gravity of 3.12 and compressive strength of 27.5, 42 and 58 (Mpa) at 2, 7 and 28 days, respectively (according to the producer).

Quartz sand: Natural quartz sand was obtained from Akpoha River in Afikpo North Local Government Area of Ebonyi State in Nigeria. The quartz sand used has 0.5mm maximum diameter and is classified as very fine sand (Alessandra *et al.*, 2007).

Acacia gum and Carboxy methyl cellulose (CMC): These were supplied by Glisco Laboratory Chemicals, Enugu state, Nigeria. They were used as supplied.

Equipment

i. Compressor (Wallace C862030)
ii. Tensometer (IT15MAT20)
iii. Flexometer (Wallace C82075)

Compounding of Ceramic Tile Adhesive

The trial formulations used for the production of the ceramic tile adhesive samples are presented in Table 1. Calcium carbonate (the standard filler used in the production of ceramic tile adhesives) was used in this study. The level of calcium carbonate used as filler in the formulation was varied from 0-16% by weight. The formulation is a modification of the method proposed by Jenni *et al.* (2005). This was necessary due to environmental differences and the source of materials used. Variations in filler level helped to optimize the effect of the additives on bond strength and other mechanical properties of the adhesive. After some preliminary tests, the sample containing 12% filler was chosen for the analysis. The quality parameters of the acacia gum-ceramic tile adhesive were determined and compared with those of Top Fix, a popular commercial brand in Nigeria produced by Purechem Companies, Ogun State, Nigeria. Top Fix was used as the reference standard in this work since it is an existing brand that has gained wide acceptability over the years in the Nigerian market.

Testing of ceramic Tile Adhesive Quality Parameters

Bond Strength

Standard test methods such as BS5980:1980 provides general evaluation of tile adhesives bond strength under laboratory conditions (Andcic *et al.*, 2009). However, pull-off test which can be classified as a near- to-surface, partially destructive method was improvised to evaluate the adhesion of the tiling system. In this method, bond strength was determined based on modified BS 5980:1980 principles. Concrete slabs with dimensions of 350mmx200mmx70mm were prepared. Ceramic tiles of 350mmx200mm size were cut. The tile mortar was thinly spread on a section (200mmx200mm) of the slab surface leaving part of the surface (150mmx200mm) free. The tile was laid on the concrete surface on which the mortar had been applied. The free end of the slab was clamped against a table top and force (load) was applied via a loop around the free end of the tile.

Table 1. Formulation of ceramic tile adhesive using acacia gum and various wt% of $CaCO_3$ filler

Components	Weight% of components							
Formulation	CTA0C	CTA4C	CTA6C	CTA8C	CTA10C	CTA12C	CTA14C	CTA16C
Cement	47.0	43.0	41.0	39.0	37.0	35.0	33.0	31.0
Quartz sand	52.0	52.0	52.0	52.0	52.0	52.0	52.0	52.0
$CaCO_3$	0.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0
CMC	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Acacia gum	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

The force was gradually increased until a point when pull-off between the two surfaces was noticed. The value of the force, x, was regarded as the adhesive bond strength expressed in $(\frac{N}{40000mm^2})$.

The value of x was converted to Y expressed in paschal $(\frac{N}{m^2})$ using the following formula:

$$Y = 25x$$

Where x = $\frac{N}{40000mm^2}$ (measured)

Y = $\frac{N}{m^2}$ (S.I unit of pressure)

25 = a constant (factor).

Mechanical Properties

Maintaining constant water content of 25.5 ml to 100g of dry mix, a set of 8 samples of ceramic tile adhesive mixtures was prepared. The compressive strength of the adhesive was determined with Wallace C862030 Compressor, the tensile strength was measured using IT15MAT20 Tensometer and the flexural strength was obtained using Wallace C82075 Flexometer. The tests were conducted after 2 days, 7 days and 28 days of application of the adhesive as shown in Table 2.

RESULTS AND DISCUSSION

The results of bond strength and mechanical properties are presented in Table 2.

From Table 2 and Fig 1, it is evident that the bond strength of acacia gum-ceramic tile adhesive (acacia gum-CTA) is comparable to that of Top Fix. The slight difference in value can be attributed to many factors among which are: (1) the type of redispersible polymer powder (which was reported in literature as one of the main components of ceramic tile adhesive) and (2) the difference in formulation which in the case of Top Fix is a guarded Company secret. In addition, synthetic RPP are high precision materials which may contain little or no impurities. This is unlike acacia gum (natural plant exudates) which contains other components that have no adhesion property (Nuhu *et al*., 2009). The effects of such components on bond strength cannot be ruled out. Again, it has been reported that industrial formulations incorporate other components aside the basic ingredients of ceramic tile adhesive (Schulze and Kilermann, 2001). Interestingly, the bond strength of acacia gum-CTA determined after 2 days was found to be very close in value to that of Top Fix.

This similarity in bond strength values was maintained after 7 days and 28 days of application. The compressive strength and tensile strength showed the same behaviour. This is not unexpected since both properties have some relationship with bond strength. The degree of adhesion of ceramic tile adhesive components to one another which helps the components to compact and prevent voids in the dry mortar is manifest in the compressive strength of the adhesive. Acacia gum-CTA has lower values of compressive strength than that of Top Fix. This obviously means that the adhesion of the acacia gum-CTA components to one another is lower than that of Top Fix. The tensile strength of ceramic tile adhesive measures the ability of the adhesive to stretch without breaking (Andcic *et al*., 2009).

Table 2. Bond strength and mechanical properties of acacia gum ceramic tile adhesive and Top Fix

Property	Bond Strength (KPa)			Compressive Strength (MPa)			Tensile Strength (KPa)			Flexural Strength (MPa)		
Period (days)	2	7	28	2	7	28	2	7	28	2	7	28
Acacia gum adhesive	6.4	9.13	11.48	5.5	11.0	12.4	15.7	15.8	16.0	2.3	2.5	3.0
Top Fix	6.5	9.2	11.6	6.0	11.8	12.8	15.7	16.0	16.4	2.2	2.4	2.8

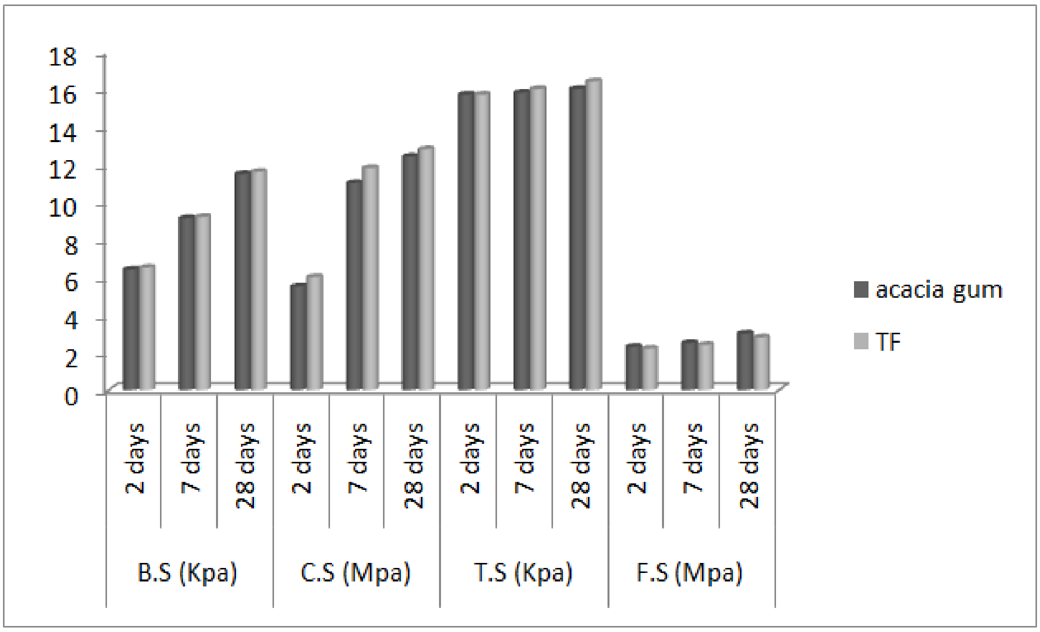

Fig. 1. Comparison of bond strength and mechanical properties of acacia gum ceramic tile adhesive and Top Fix

Evaluation of tensile strength helps to determine the ability of the adhesive to maintain bond strength even when the tiling system expands. The closeness in tensile strength of acacia gum-CTA to Top Fix (Table 2 and Fig 1) is a reflection of the closeness in their bond strength values. This is perhaps also responsible for the closeness in their flexibility (though the flexibility of acacia gum-CTA is higher than that of Top Fix, as reflected in the flexural strength values). This observation is in agreement with the fact that the slightly lower bond strength of acacia-gum-CTA permits the components to slide over one another more easily than in Top Fix system.

Conclusion

The applicability of acacia gum as a substitute for redispersible polymer powder in ceramic tile adhesive has been established. Acacia gum impacts good bond strength, tensile strength, compressive strength and flexural strength in ceramic tile adhesive. As evident in the values, acacia gum-filled ceramic tile adhesive had bond strength, tensile strength, compressive strength and flexural strength which were close to those of Top Fix, a popular brand of ceramic tile adhesive in Nigeria.

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