A STUDY ON SYNTHESIS AND TESTING OF POLYMER MODIFIED CONCRETE

By

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Abstract
The contribution of concrete-polymer composites, particularly polymer-modified cement concrete and mortar, to sustainable construction technology is manifold. By polymer modification of concrete, an interpenetrating network of polymer and cement hydrates is generated in which the aggregates are embedded. The synergetic action of polymers and cement concrete offers great opportunities for improvement and a wide range of new and innovative properties and applications. Purpose of this study was to assess the effects due to the addition of polymers on the performance characteristics of concretes. Embedded reinforcement concretes with higher levels of replacement will improve the knowledge on this subject and also provide useful information to concrete users. This paper is focused on the use of polymers, to study the change in properties of cement mixtures of standard consistence. Much attention has been given to the structural properties of cement-matrix composites. Standard sample was first synthesized using cement, sand and water. Known percentages of polymers were then added in the mixture, mortar was prepared and setting times, soundness and compressive strength were determined to test the change in the properties of the mortar after polymer addition.

Key words : Polymer, Concrete

Introduction

The worldwide demand for high-performance cement-based materials has tremendously increased during last few decades. Economical and environmental considerations had a crucial role in supplementary cementing material usage as well as better engineering and performance properties [1-2]. The improvement of concrete properties basically serves to identify a high-performance concrete; rheological characteristics and durability [3]. Cement-based materials are dominant structural materials for civil infrastructure. The addition of a minor amount of a polymer to a cement mix can significantly change the properties of the resulting material, which is known as a polymer-modified cement-based material. These additives, known as admixtures, can be in the form of polymer particles, short polymer fibers or liquids [4]. Fibers are in general more effective than particles for toughening the cement-based material, but they are more expensive. Low cost is critical to the practical viability of a cement-based material [5].

The use of admixtures is a relatively convenient way of improving properties of cement-based materials. Techniques involving special mixing, casting or curing procedures tend to be less attractive, due to the need for special equipment in the field, although other admixtures are also available like latex and short fibers, which are more expensive [6-8]. Cement; is a powder of alumina, silica, lime, iron oxide, and magnesium oxide burned together in a kiln, finely pulverized and used as an ingredient of mortar and concrete. Concrete is made by mixing a cementing material, mineral aggregate (as sand and gravel) with sufficient water to cause the cement to set and bind the entire mass. [9]. Portland cement; as defined by the European Standard EN197.1 is a clinker with two-thirds by mass of calcium silicates ($3CaO.SiO_2$ and $2CaO.SiO_2$) and rest is aluminium and iron-containing clinker phases. The ratio of CaO to SiO_2 shall not be less than 2.0. The magnesium content (MgO) shall not exceed 5.0% by mass [10]. There are different standards for classification of Portland cement. The standards primarily used in USA are ASTM C 150. There are five types of Portland cements with variations of the first three according to ASTM C 150. Type I, Type II, Type III, Type IV, Type V, Types I a,

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II a, and III a [10]. Commercial Cements include Portland Cement, Sulphate Resistant Cement, Portland Pozzolan Cement, Portland Silica Fume Cement, Expansive Cement, White Blended Cement, Colored Cement, Very Finely Ground Cement, High Alumina Cement, Sorel Cement, Masonary Cement, Oil well Cement, Silicate Cement [11-15]

Usually only five percent of polymers are incompatible with hydraulic concrete and are non-ionic. The type of surfactant used to disperse and stabilize the polymer is the essential consideration. Different manufacturers have different proprietary combinations. One process of cement hydration, polymer modifications add a process of coalescence. As cement hardens, there form small spaces between the aggregate particles. These spaces allow water to penetrate, and do damage in freezing conditions. Polymer particles coalesce to fill these voids. That's why the concrete becomes less permeable and better protected against freezing. Interestingly, polymer concrete does not produce bleed water. It makes an excellent overlay because it needs very little finishing. The polymer, bind not only to concrete and aggregate in the mixture, but also with the underlying concrete. That is why it is used to resurface concrete. Polymer particles used as admixtures can be in the form of a dry powder or an aqueous dispersion of particles [16]. Short fibers rather than continuous ones like Polypropylene, Polyethylene Polyurethane Epoxy Resins and Acrylic Fibers are used. Recycled plastics and tire rubber can also be utilized as admixtures. The bond between crumb rubbers and cement can be enhanced by the addition of latex. Recycled waste latex paint is also used as an admixture [17-20]. Different polymers (rather than polymer-modified cement-based materials) like epoxy, polyurethane, silane, siloxane, polyvinyl chloride, latex, methacrylate are used for coating concrete, fill gaps, concrete repair, structural connection and sealing, [21-34]. Addition of polymers effect mechanical properties [17], vibration damping capacity and bond strength to reinforcements [35-36].

Experimental :

Materials :

Materials used in this investigation were Portland cement, Natural sand, water, natural latex, polyurethane and acrylic resin. Portland cement was obtained from Maple Leaf Pakistan Ltd. Fineness of cement used was determined by sieving the cement from BS mesh number 170 test sieves and recording the residue which shall not exceed 10% for OPC cement when calculated by weight to the original weight of the cement. Natural sand was utilized as a cementitious material is obtained from local market. The aggregate was a mixture of natural sand and cement. Commercially available natural latex, polyurethane and acrylic resin were used as polymer additives in aggregate and are used without any pretreatment. In order to investigate the effects of different polymers on the performance properties of concrete 10 and 20% polymer addition in concrete mixtures were employed. The control mix contained only Portland cement as the binder. The water-cementitious material (w/cm) ratio was kept constant at 0.3 for all mixes. All concretes were mixed in accordance with ASTM C192 standard in a power-driven revolving pan mixer. Concrete cubes of 2.75 inch diameter and 1.57 inch height in size are made for initial setting time and final setting time determinations, and test specimen cubes having lengths of side of 2 inch and an area of 4.0 sq. inch were cast in steel moulds for the study of the compressive strength and soundness.

Tests Methods

Setting Time

Vicat apparatus is used for the determination of initial and final setting time which is as per accordance with BS 12 and ASTM C 150 standard. 400 gm cement and 110 – 120 gm of water was mixed in a vicat mould on a non porous plate for 4 minutes at a temperature of 66 ±2 °F in an atmosphere of at least 90% relative humidity and away from droughts. Neat cement paste was formed by gauging cement with the quantity of water required to give paste of standard consistence. The mould was completely filled, and surface of the paste is smoothed off with the top of mould cleaner. For the determination of initial setting time, the test block confined in the mould of vicat apparatus resting upon the plate was placed under rod bearing needle. The needle was lowered gently, made to contact with the surface of the test block, released and allowed to sink in. This process was repeated until the needle does not penetrate beyond a point approximately 5mm from the bottom of the mould. The time when water was added to cement and the time at which the needle ceases to penetrate the test block were recorded as initial setting time. For determination of final setting time the needle of the vicat apparatus was replaced by the needle with an annular attachment. The cement was considered as finally set when upon applying the needle gently to the surface of the test block, needle only makes an impression; while annular attachment fails to do so. Ideally initial setting time should not be less than 45 mins for BS 12 and for ASTM C 150 standards while final setting time should not be more than 600 min for BS12 and 375 min for ASTM C150 standards.

Soundness

Soundness measurements were conducted according to BS 4550 section 3.7. Paste was gauged by mixing 400 gm cement and 110 - 115 gm water for 4 mins to make a paste of standard consistence. Mould was placed on glass and filled with cement paste. Care was being taken to keep the split of the moulds gently closed. Mould was covered with a piece of glass upon which a small weight was placed and the whole apparatus was submerged in water at a temperature of 66 ± 2 °F and left there for 24 hours. The distance separating the indicator point was measured and the mould was submerged again in water at a temperature prescribed above which brought to boiling for 1 hour. The mould was removed from the water allowed to cool and the difference between the two measurements represents the expansion of cement.

Compressive Strength

Compressive strength measurements were conducted using compression testing machine according to ASTM C150 standard. One part by weight of cement to three parts by weight of standard sand was mixed dried with a trowel on a non porous plate for 1 min as per BS 4550 Section 3.4 for mixing. Sand weights taken after sieving from BS mesh are -16 – +30 = 28 gm, -30 – +40 = 384 gm, -40 – +50 = 619 gm and -50 – +100 = 344 gm are mixed to make paste. Three cubes are taken and material for each cube was mixed separately. Quantities of cement, standard sand and water taken were 1375 gm, 500 gm and 242 gm respectively. Water was added in it and sample is placed for 4 minutes. The test specimen cubes having lengths of side of 2 inch and an area of 4 sq. in were used. Cubes were placed in an atmosphere of at least 90% relative humidity at a temperature of 66±2 °F for 24 hours. In order to reduce evaporation, top of the moulds were covered. After 24 hrs cubes were removed from the moulds and then submerged in water. Cubes were tested immediately on removal from the water. Three cubes were tested for compressive strength at 3 days. The final compressive strength was the average of the compressive strength values of three cubes. The cubes were compressed using compression testing machine with their sides without any packing other than steel plate and load was steadily and uniformly applied, starting from zero, at a rate of 351.5 Kg/sq.cm per min. The compressive strength was calculated from the crushing load and the area over which the load is applied. The average compressive strength of the three mortar cubes, prepared, stored and tested by the ASTM standard procedure for ordinary Portland cement should not less than 154 Kg/sq.cm and 239 kg/sq.cm for 3 days and 7 days respectively.

Observations and Calculations :

Results and Discussions :

Summary of test results regarding the initial setting time, final setting time and soundness and compressive strengths for 10 and 20 % polymer addition are given in Table 1 and 2 and graphically depicted in Figs. 2-15.

Setting Time

Change in setting time of concrete by addition of polymer is given in Fig. 1-6. It is clear that rate of setting decreases systematically with an increase in percentage of polymer addition (from 10 to 20%), and the gradients of setting time tends to decrease with increase in polymer addition. It was found that the rate of setting time of polymer modified cement is lower than that of standard concretes, depending on added polymer contents. The initial setting time values for the standard cement are 249 minutes. Range of initial setting time for polymer modified concrete is from 0.1 to 250 minutes and range of final setting time is from 2 to 450 minutes which is less than initial and final setting time of standard cement. Acrylic resin and Polyurethane gave small decrease in the setting times while addition of natural latex decreases the setting time remarkably in the range of 0.3 to 40 minutes which is 250-450 minutes on average for standard cement paste.

Soundness

The change in soundness rate with concrete and polymer modified concretes are given in Fig. 7-9. It is clear that soundness increases systematically with an increase in percentage of polymer added in concrete paste of standard consistence. Generally, natural latex modified concrete have greater soundness values than acrylic resin and polyurethane. It was found that the rate of soundness of concrete was about 1.0 and that of polymer modified concrete was in range of 1.25 – 2.50, depending on type and percentage of polymer contents. For natural Latex this value is maximum ranging up to 2.50 on average for 10% and 20% latex addition.

Compressive Strength

The data concerning the variation of compressive strength with respect to polymer addition in concretes containing 10% and 20% polymer is presented in Figures 10-15. The strength values for the cement paste of standard consistence and polymer modified concretes ranged from 955 - 1400 lb/sq.in and 300 - 1300 lb/sq.in for polymer modified concrete for 3 and 7 days respectively depending mainly on type of polymer added and curing time. The figure indicates that there was a systematic decrease in compressive strength with the increase in polymer contents. A noticeable strength reduction is observed with natural latex addition. For acrylic resin and polyurethane strength values are higher than that of natural latex.

Conclusions :

1. Polymer addition decreased the initial and final setting times of concrete paste as compared with the paste of standard consistence. Natural latex addition decreased the setting time remarkably to very low extent in comparison to acrylic resin and polyurethane addition. With the addition of acrylic resin and polyurethane setting times decreased but the difference was smaller than setting time of cement mixture of standard consistence. By adding 10% quantity of Polyurethane, initial setting time and final setting time decreases to some extent but further increase in its quantity cause an increase in the setting time.

2. Generally, there was a systematic decrease in compressive strengths with the increase in polymer contents, especially for natural latex. Incorporation of 20% polymer addition in concrete caused decrease in compressive strengths further than addition of 10% polymer addition.

3. Polymer modified concrete exhibited marginally high soundness values than standard concrete. An increase in polymer contents (from 10 to 20%) increases the soundness by total immersion and capillary action, particularly under wet condition. It was observed that the concretes containing 20% polymer showed increased values of soundness than 10% addition.

4. On the average natural latex addition show remarkable change in the properties of cement mixture than the addition of other polymers. Initial and final setting time are decreased thus setting the cement quickly instead taking long time to settle. Also soundness values show large increase in its value for natural latex than acrylic resin and polyurethane. But addition of natural latex decreased the compressive strength of the cement mixture to very low values than acrylic resin and polyurethane.

Sr.No	Tests	Time	Units	Standard Cement	Polymer addition = 10%		
					Acrylic Resin	Natural Latex	Polyurethane
1	Initial Setting Time (min)	Min	Minutes	249	231	20	235
2	Final Setting Time (min)	Min	Minutes	436	420	40	435
3	Soundness		mm	1	1.16	2.21	1.25
4	Compressive Strength (	3 days	lb/sq in	955	371	298	931
		7 days	lb /sq in	1400	908	560	1228

Table-1 : Summary of test results for 10% Polymer addition

Sr.No	Tests	Time	Units	Standard Cement	Polymer Addition = 20%		
					Acrylic Resin	Natural Latex	Polyurethane
1	Initial Setting Time (min)	Min	Minutes	249	215	0.3	244
2	Final Setting Time (min)	Min	Minutes	436	402	2	433
3	Soundness		mm	1	1.51	2.6	1.65
4	Compressive Strength	3 days	lb /sq in	955	340	188	940
		7 days	lb /sq in	1400	807	583	1360

Table-2 : Summary of test results for 20% Polymer addition

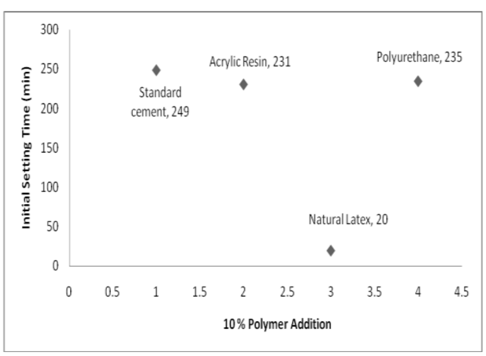

Fig-1 : Comparison of initial setting time values of standard cement paste with initial setting time values after 10% polymer addition

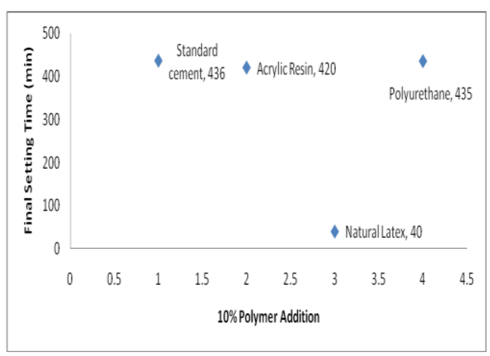

Fig-2 : Comparison of final setting time values of standard cement paste with final setting time values after 10% polymer addition

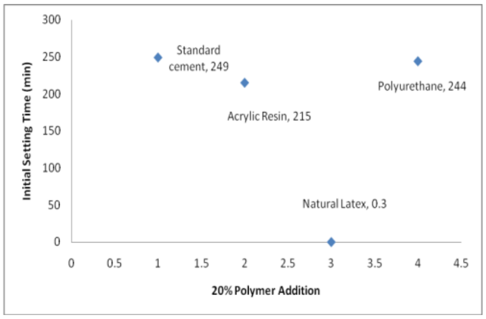

Fig-3 : Comparison of initial setting time values of standard cement paste with initial setting time values after 20% polymer addition

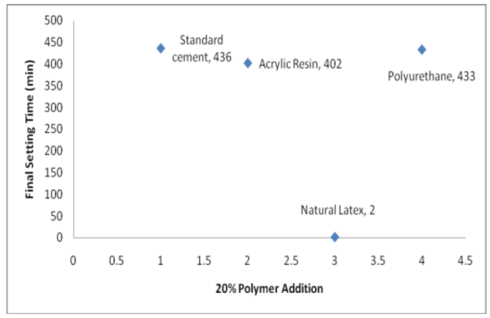

Fig-4 : Comparison of final setting time values of standard cement paste with final setting time values after 20% polymer addition

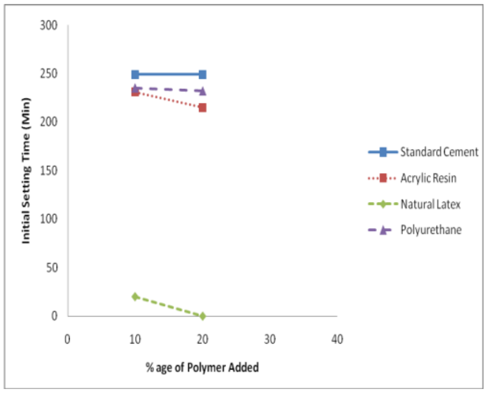

Fig-5 : Effect of polymer addition (from 10-20%) on initial setting time values in standard cement paste

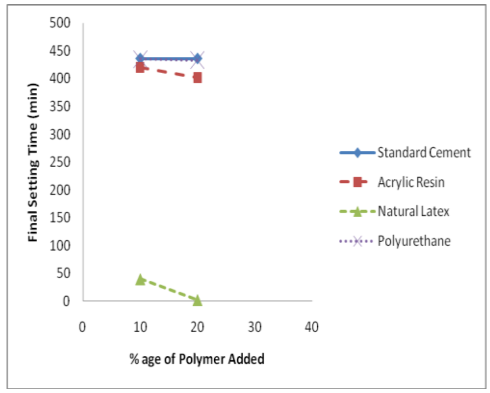

Fig-6 : Effect of polymer addition (from 10-20%) on initial setting time values in standard cement paste

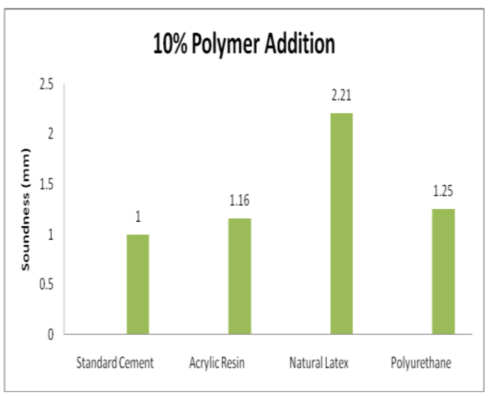

Fig-7 : Comparison of soundness values of standard cement paste with soundness values after 10% polymer addition in cement Paste

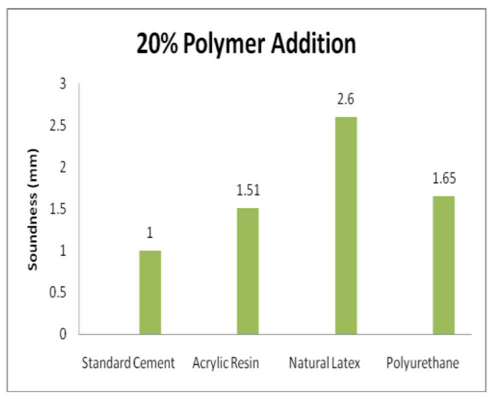

Fig-8 : Comparison of soundness values of standard cement paste with soundness values after 20% polymer addition in cement Paste

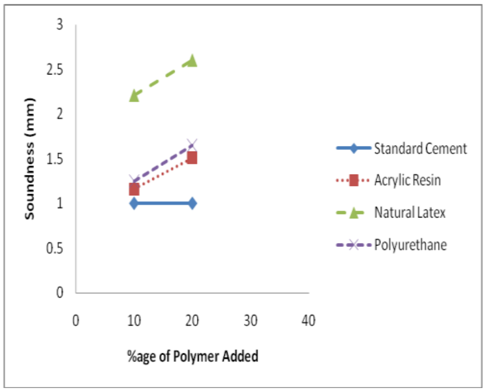

Fig-9 : Effect of polymer addition (from 10-20%) on soundness values in standard cement paste

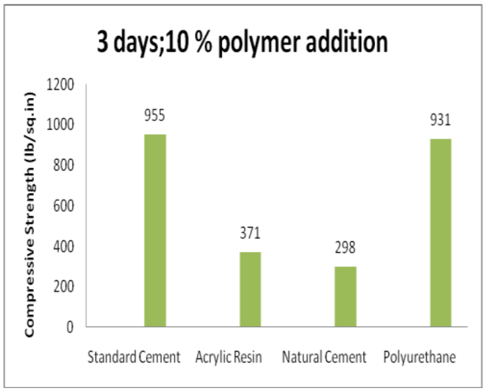

Fig-10 : Comparison of compressive strength values of standard cement paste with compressive strength values after 3 days for 10% polymer addition in cement Paste

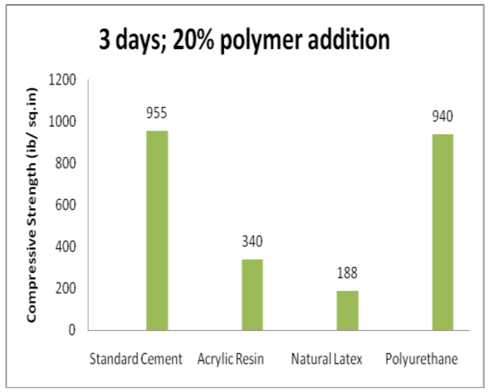

Fig-11 : Comparison of compressive strength values of standard cement paste with compressive strength values after 3 days for 20% polymer addition in cement Paste

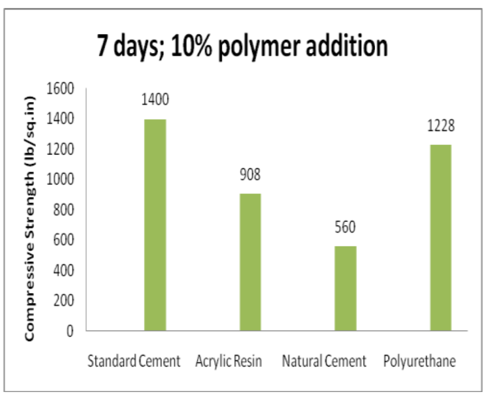

Fig-12 : Comparison of compressive strength values of standard cement paste with compressive strength values after 7 days for 10% polymer addition in cement Paste

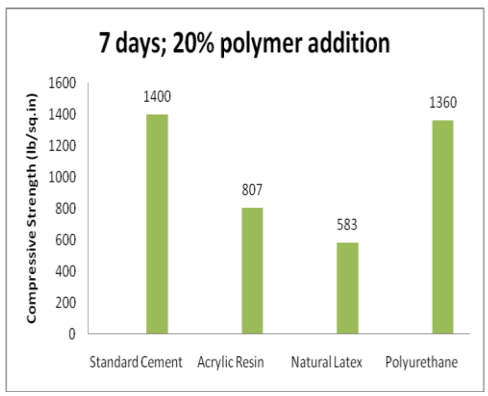

Fig-13 : Comparison of compressive strength values of standard cement paste with compressive strength values after 7 days for 20% polymer addition in cement Paste

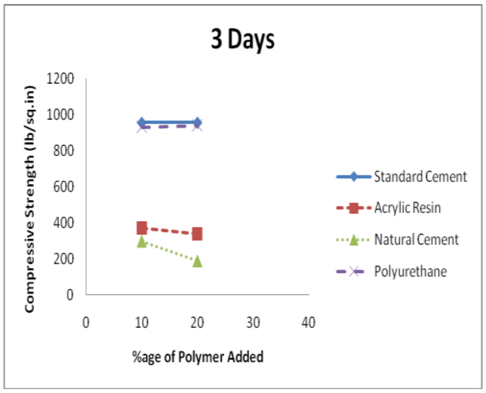

Fig-14 : Effect of polymer addition (from 10-20%) on compressive strength values of standard cement paste after 3 days

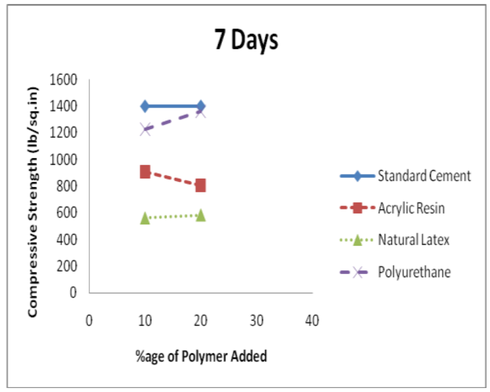

Fig-15 : Effect of polymer addition (from 10-20%) on compressive strength values of standard cement paste after 7 days

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