Kode/Nama Rumpun Ilmu: 421/Teknik Sipil
Bidang Fokus : Material Maju

LAPORAN AKHIR

PENELITIAN BERBASIS KOMPETENSI

Efek Jangka Panjang Penggunaan Nano Silika Terhadap Sifat Mekanik dan Durabilitas Beton

Tahun ke 1 dari rencana 2 tahun

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Sesuai dengan Kontrak Penelitian Tahun Anggaran 2018
Nomor : 008/KM/PNT/2018, Tanggal 06 Maret 2018

UNIVERSITAS PANCASILA

NOVEMBER 2018

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Biaya Keseluruhan	:	Rp 307,988,000

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UNIVERSITAS PANCASILA FAKULTAS TEKNIK DEKAN

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IDENTITAS DAN URAIAN UMUM

1. Judul Penelitian : Efek Jangka Panjang Penggunaan Nano Silika Terhadap Sifat Mekanik dan Durabilitas Beton
2. Tim Penelitian

No	Nama	Jabatan	Bidang Keahlian	Instansi Asal	Alokasi Waktu (Jam/ Minggu)
1	Dr. Ir. Jonbi, MT., MM., MSi	Ketua	Struktur dan Material	Universitas Pancasila	10
2	Dr. Partogi H. Simatupang,MT	Anggota	Struktur dan Material	Universitas Cendana	10

3. Objek Penelitian: penggunan nano silika dalam campuran beton untuk f'$_c$ 35 MPa , f'$_c$ 45 MPa, f'$_c$ 50 MPadan f'$_c$ 70. Pada tahun ke-1, dilakukan penelitian efek nano silika pada beton dengan f'$_c$ 35 MPa dan f'$_c$ 45 MPa (*moderate- strength concrete*) pada umur beton 28, 56, 91 dan 365 hari. Pada tahun ke- 2. dilakukan untuk beton f'$_c$ 50 dan f'$_c$ 70 (*High Strength Concrete*), sehingga penelitian selama dua tahun dihasilkan efek jangka panjang penggunaan nano silika untuk dua tipe beton.
4. Masa pelaksanaan
   Mulai : Bulan Juli tahun 2018
   Berakhir : Bulan November tahun 2019
5. Usulan Biaya DRPM Ditjen Penguatan Risbang
   - Tahun Ke-1 : Rp. 162.100.000 , ***dana yang disetujui 146.500.000***
   - Tahun ke-2 : Rp. 162.100.000
6. Lokasi Penelitian: Lab. Universitas Pancasila, Lab. Pusat survei Geologi, dan Lab ITB, Bandung
7. Temuan yang ditargetkan suatu temuan yang menjelaskan bagaimana efek jangka panjang penggunaan nano silika, dimana penelitian selama ini telah membuktikan terjadi peningkatkan kuat tekan dan durabilitas pada beton umur 28 hari.
8. Kontribusi mendasar pada suatu bidang ilmu adalah temuan baru (*novelty*) penggunaan nano silika untuk jangka panjang. Temuan ini penting karena penelitian selama ini hanya pada efek pada beton umur 28 hari. Implikasinya dengan mengetahui efek jangka panjang penggunaan nano silika, akan dihasilkan suatu nilai faktor keamanan untuk menentukan nilai mekanik dan durabilitas beton dalam perencanaan struktur bangunan.

9. Jurnal ilmiah yang menjadi sasaran dan tahun rencana publikasi adalah jurnal inetrnasional bereputasi 1 artikel pada tahun pertama dan 1 artikel pada tahun kedua yang dimuat pada salah satu jurnal:
   - KSCE Journal of Civil Engineering (impact factor: 0.600)
   - Structural Concrete (impact factor: 1.023)
10. Rencana luaran wajib berupa jurnal ilmiah ineternasional bereputasi 1 artikel/tahun, dan buku ajar edar nasional akhir tahun ke 2. Luaran tambahan berupa paten sederhana dalam bentuk draft pada akhir tahun ke 2.

DAFTAR ISI

Halaman

RINGKASAN

Penelitian penggunan nano silika pada beton sudah banyak dilakukan peneliti. Hasilnya memperlihatkan kuat tekan dan durabilitas beton secara signifikan meningkat. Namun sayangnya penelitian yang dilakukan sebatas pada beton berumur 28 hari (jangka pendek). Sedangkan penelitian tentang efek nanosilika pada beton berumur lebih dari 28 hari (jangka panjang) masih sangat terbatas. Untuk itu perlu dilakukan penelitian efek jangka panjang penggunaan nano silika. Penelitian ini dilakukan dalam dua tahun, pada tahun pertama dilakukan pada beton f'_c 35 MPa dan f'_c 45 MPa (*moderate-high strength*). Pada tahun kedua pada beton f'_c 50 MPa dan f'_c 70 MPa (*high strength concrete*). Prosentase nano silika yang digunakan tetap sebesar 5% dari berat binder. Pengujian sifat mekanik berupa kuat tekan, kuat tarik, kuat lentur dan durabilitas beton pada umur beton 28 hari (beton kontrol), 56, 91, 365 hari. Kemudian pada setiap benda uji tersebut dilakukan pengujian SEM dan FT-IR. Hasil penelitian yang dilakukan selama dua tahun, akan dihasilkan suatu temuan baru (novelty) berupa nilai faktor keamanan untuk menentukan nilai mekanik dan durabilitas beton.

Keyword : nanosilika, sifat mekanik, durabilitas, moderate high strength, high strength concrete

BAB I. PENDAHULUAN

1.1 Latar Belakang

Perkembangan nanoteknologi pada material telah menjadi pendorong munculnya material baru, salah satunya adalah nano silika. Penggunaan nano silika pada campuran pasta, mortar dan beton terbukti dapat meningkatkan sifat mekanik dan durabilitas beton. Hal ini didukung oleh penelitian yang dilakukan beberapa peneliti antara lain Singh et al.,2015; Hou et al.,2013; Jonbi et al., 2012.

Efek penggunaan nano silika mendapat perhatian banyak peneliti dalam beberapa tahun terakhir ini. Kong et al. (2013) melaporkan nano silika merupakan bahan yang relatif baru untuk diaplikasikan pada beton kinerja tinggi dan harganya jauh lebih tinggi dibandingkan dengan bahan pozolan lainnya, namun sangat reaktif. Nano silika sebagai material baru perlu dilakukan penelitian secara terus menerus baik dalam skala laboratorium maupun penerapan di lapangan.

Namun sayangnya penelitian tentang penggunaan nano silika ke dalam campuran pasta, mortar dan beton, dilakukan pada saat umur pasta, mortar dan beton 28 hari (jangka pendek). Sedangkan penelitian tentang efek jangka panjang yakni umur pasta, mortar dan beton lebih dari 28 hari penggunaan nano silika masih sangat terbatas.

Untuk itu penelitian efek jangka panjang penggunaan nano silika terhadap sifat mekanik dan durabilitas beton perlu dan penting dilakukan. Pada penelitian ini efek nano silika untuk beton dengan empat mutu yakni f'_c 35 MPa, f'_c 45 MPa, f'_c 50 MPa dan f'_c 70 MPa. Ke empat mutu beton tersebut adalah mutu beton yang lazim digunakan di lapangan.

Penelitian ini memiliki target capaian seperti tampak pada Tabel 1. Publikasi berupa jurnal ilmiah internasional bereputasi satu judul/tahun dan buku edar nasional pada akhir tahun ke 2. Untuk memenuhi target pencapaian tersebut, maka penelitian ini dikembangkan baik metode penelitian untuk menghasilkan temuan baru (*novelty*).

1.2. Tujuan Khusus

1. Menghasilkan temuan baru (*novelty*) tentang efek jangka panjang penggunaan nanosilika pada beton.
2. Menghasilkan suatu faktor keamanan terhadap penggunaan nano silika pada beton terhadap sifat mekanik dan durabilitas beton.

1.3. Urgensi (Keutamaan) Penelitian

Hasil penelitian yang diperoleh diharapkan :

1. Memberikan kontribusi terhadap ilmu material tentang penggunaan nano silika pada beton.
2. Memberikan kontribusi ilmu melalui jurnal internasional bereputasi.

1.4. Rencana Target Capaian Tahunan

Rencana target capaian tahunan dapat dilihat pada Tabel 1. merupakan luaran wajib dan luaran tambahan.

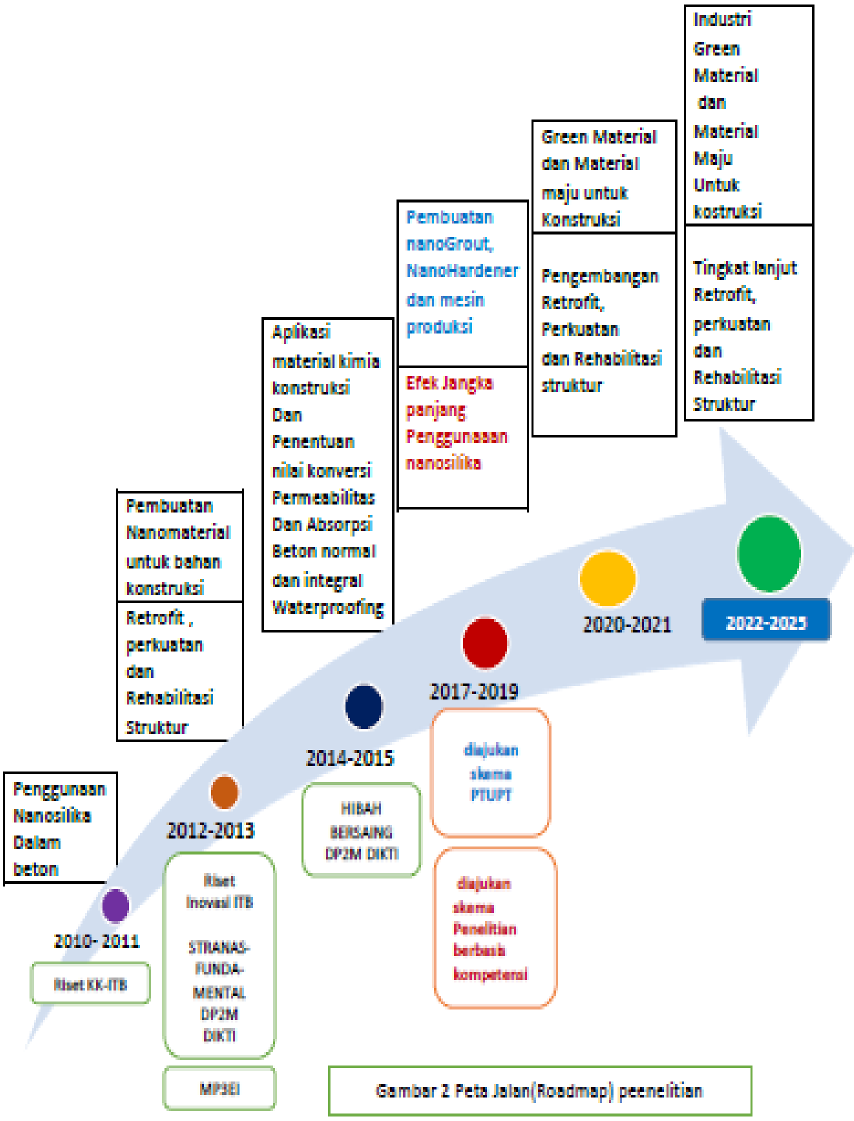
Tabel 1. Rencana Target Capaian Tahunan

No	Jenis Luaran				Indikator capaian	
1	**Kategori**	**Sub Kategori**	**Wajib**	**Tambahan**	**TS [1)]**	**TS+1**
	Artikel ilmiah dimuat dalam Jurnal	Internasional bereputasi	v		accepted/ published	accepted/ published
		Nasional terakreditasi	v		accepted/ published	accepted/ published
2	Artikel Ilmiah dimuat di prosiding	Internasional Terindeks	v		draft	Sudah dilaksanakan
		Nasional	v		sudah dilaksanakan	sudah dilaksanakan
3	Hak Kekayaan Intelektual (HKI)	Paten sederhana		v	Draft	Terdaftar
4	Buku ajar			v	*Belum/tidak ada*	*Draft*
5	Tingkat kesiapan Teknologi (TKT)		v		2	3

BAB 2. URAIAN KEGIATAN

2.1. Peta Jalan Penelitian

Peta Jalan (*Roadmap*) penelitian dapat dilihat pada Gambar 1. Pada tahun 2010-2011 penelitian tentang penggunaan nanosilika untuk beton. Kemudian tahun 2012-2013 pembuatan nanomaterial dengan nanoteknologi untuk konstruksi; tahun 2014-2015 penelitian tentang aplikasi material konstruksi dan menentukan nilai konversi permeabilitas dan absorpsi pada beton normal dan beton Intergral waterproofing. Penelitian tersebut di atas didana oleh ITB dan DP2M DIKTI. Untuk tahun 2017-2019 ada 2 penelitian yang dilakukan: pertama pengembangan NanoGrout dan NanoHardener untuk menciptakan entrepreneur material maju. Penelitian kedua tentang efek jangka panjang penggunaan nanosilika terhadap sifat mekanik dan durabilitas beton.



Gambar 2 Peta Jalan(Roadmap) peenelitian

Berdasarkan penelitian dan publikasi yang telah dilakukan tim pengusul serta publikasi terakhir tentang nanosilika maka penelitian tentang efek jangka panjang penggunaan nanosilika tersebut memiliki potensi kontribusi perkembangan penggunaan nanosilika khususnya pada beton.

2.1. Perkembangan riset tentang nano silika

Efek penggunaan nano silika terhadap peningkatan sifat mekanik pada beton dan mortar sudah dilakukan oleh beberapa peneliti. Singh et al. (2015) membandingkan efek dua jenis serbuk nano silika dan koloidal terhadap sifat mekanik beton. Hasil penelitian menunjukkan bahwa nano silika bubuk efektif untuk memperbaiki sifat mekanik semen mortar. Sedangkan Mohammad Bolhassani and Mohammadreza Samani (2015), menyatakan kekuatan tekan tidak terpengaruh oleh bentuk partikel nano silika baik serbuk dan koloidal namun hanya sensitif terhadap *specific surface area* (SSA) partikel nano silika. Persentase nano silika yang rendah tidak meningkatkan kinerja mortar dalam *curing* jangka panjang.

Hou et al. (2013) melaporkan penambahan nano silika koloidal 5% dan Fly ash 40%, secara signifikan meningkatkan proses pengerasan pasta semen fly ash, dan meningkatkan kuat tekan pada pasta semen. Menurut Jonbi et al. (2012), prosentase nano silika optimum dalam campuran beton adalah 5 % dan silika fume 5%.

Haruchansapong et al. (2014), menyatakan nano silika dapat meningkatkan sifat komposit semen melalui mekanisme yang berbeda, Nano silika dan silika fume, adalah pozzolan yang sangat reaktif dan dapat mengubah kalsium hidroksida (CH) untuk membentuk C-S-H.

Torabian Isfahani et al. (2016), melaporkan efektivitas penambahan dosis nano silika tertentu ke dalam campuran beton dengan sifat mekanik (kuat tekan dan kuat taarik) rendah, efek yang ditimbulkan lebih terlihat, sementara untuk kekuatan yang lebih tinggi efektifitas nano silika cenderung berkurang.

Mohamed et al. (2016), menyatakan kuat tekan, kuat tarik, dan kuat lentur untuk semua campuran yang mengandung silikafume dan Nano silika setelahnya 28 hari meningkat sama dengan campuran pada beton.

Biricik & Sarier, (2014), melaporkan dalam penggunaan nano silika perlu diperhatikan efeknya terhadap permeabilitas, absorpsi, kemudahan kerja, durabilitas dan creep pada beton dan mortar. Sementara Schmidt et al. (2013), menyatakan reaksi pozolan silika fume lebih tinggi dibandingkan dengan bahan pozolan lainya dikarenakan memiliki kemurnian silikon dioksida tinggi dan luas permukaan tinggi.

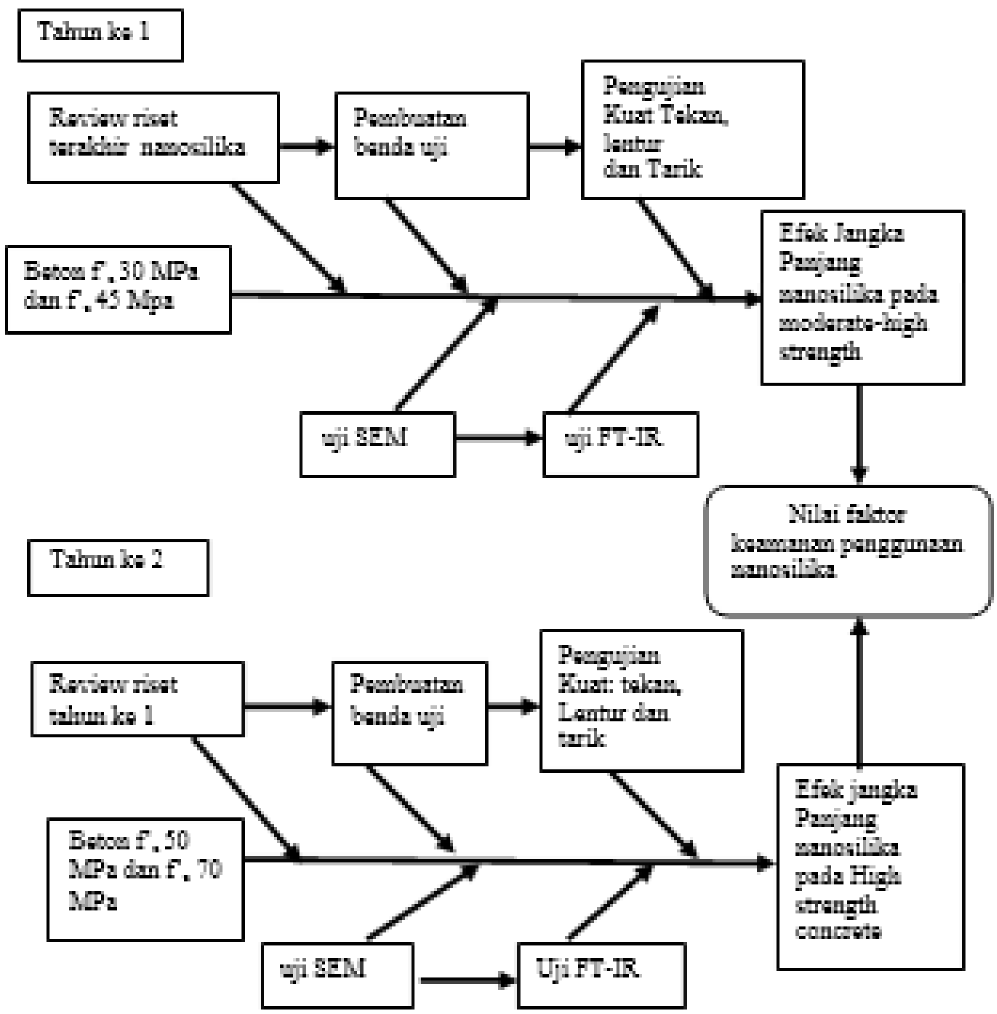
Jalal et al. (2012), melaporkan nano partikel dapat meningkatkan hidrasi dan membuat matriks semen lebih homogen dan kompak. Kemudian menurut Ortel et al. (2013), efek nanosilika terjadi pada hidrasi semen dan pengembangan mikrostruktur Ultra High Performance Concrete.

Berdasarkan riset tentang nano silika dapat dilihat bahwa nano silika merupakan suatu material yang sangat potensial digunakan pada pasta, mortar dan beton karena hasil yang ditimbulkannya, namun hampir semua penelitian pada umur pasta, mortar dan beton 28 hari. Hal ini yang menjadi gap bagaimana efek nano silika untuk jangka panjang. Oleh karenanya penelitian tentang efek jangka panjang menjadi penting untuk mengatasi gap yang ada.

Penelitian ini diharapkan akan memberi kontribusi mendasar pada suatu bidang ilmu melalui temuan baru (*novelty*) penggunaan nano silika untuk jangka panjang. Temuan ini penting karena penelitian selama ini hanya pada efek pada beton umur 28 hari (efek jangka Pendek). Oleh karenanya dengan mengetahui efek jangka panjang penggunaan nano silika pada beton, akan dihasilkan suatu nilai faktor keamanan untuk menentukan nilai mekanik dan durabilitas beton dalam perencanaan struktur bangunan.

BAB 2. METODE PENELITIAN

Metode penelitian dilakukan melalui tahapan penelitian seperti terlihat pada Gambar 3, dengan jangka waktu penelitian selama dua tahun. Penelitian ini telah dimulai melalui penelitian pada tahun sebelumnya yang telah dijelaskan dan dapat dilihat pada Gambar 2, dengan demikian penelitian ini merupakan penelitian lanjutan. Tahapan penelitian pada tahun pertama dimulai dengan mereview riset terakhir tentang material nanosilika. Pembuatan benda uji dilakukan dengan menambahkan nanosilika sebanyak 5% dari berat binder. Jumlah benda uji sebanyak 3 buah untuk setiap mutu beton dan pada umur 28, 56, 91 dan 365 hari. Untuk uji SEM dan FTIR benda uji sebanyak 2 untuk setiap mutu beton dan umur beton.



Gambar 3. Tahapan penelitian selama 2 tahun

Selanjutnya dilakukan pengujian seperti terlihat pada Tabel 2. sesuai standar ASTM berupa: kuat tekan, kuat lentur dan kuat Tarik, pengujian dilakukan di laboratorium Universitas Pancasila. Kemudian pengujian SEM dilakukan di Pusat Geologi Bandung dan FT-IR di Lab. Farmasi ITB. Hasil tahapan penelitian pada tahun pertama berupa efek jangka panjang penggunaan nano silika pada beton f'_c 35 MPa dan f'_c 45 MPa (*moderate-high strength)*, yang akan dipublikasikan pada jurnal ilmiah yang bereputasi. Ini merupakan luaran wajib, disamping itu dihasilkan luaran tambahan seperti terlihat pada Tabel 1

Tabel 2. Pengujian untuk beton moderate-high strength- high strength soncrete

Benda uji	**Pengujian pada beton umur 28, 56, 91 dan 356 hari**				
Tahun ke 1	Kuat tekan	Kuat lentur	Kuat tarik	SEM	FT-IR
f'_c 35	✓	✓	✓	✓	✓
f'_c 45	✓	✓	✓	✓	✓
Tahun Ke 2	✓	✓	✓	✓	✓
f'_c50	✓	✓	✓	✓	✓
f'_c70	✓	✓	✓	✓	✓

Pada Tahun kedua dimulai dengan review riset tahun pertama selanjutnya pembuatan benda uji untuk beton f'_c 50 MPa dan beton f'_c 70 MPa (*high strength concrete*), masing-masing 3 buah untuk setiap f'_c. Kemudian dilakukan pengujian di universitas pancasila yakni pengujian : kuat tekan, kuat lentur dan kuat Tarik. Pengujian SEM di Pusat Geologi Bandung dan FT-IR di Lab. Farmasi ITB. Pada tahaun ke 2 juga dihasilkan jurnal internasional bereputasi sebagai luaran wajib dan sebagai luaran tambahan paten sederhana dan draft buku edar Nasional. Hasil akhir penelitian tahun ke 1 dan tahun ke 2, diperoleh suatu faktor keamanan nilai mekanik dan durabilitas beton dari penggunaan nano silika pada beton *moderate-high strength* dan *high strength concrete.*

BAB 5. HASIL DAN LUARAN YANG DICAPAI

Hasil yang sudah diperoleh sampai bulan **November 2018** progres sudah mencapai 100%, seperti terlihat pada Tabel. 3.

Benda uji	**Pengujian pada beton umur 28, 56, 91 dan 356 hari**				
Tahun ke 1	Kuat tekan	Kuat lentur	Kuat tarik	SEM	FT-IR
f'_c 35	✓	✓	✓	✓	✓
f'_c 45	✓	✓	✓	✓	✓

- **Persentase Kemajuan kegiatan penelitian : 100 %**

Terkait paper Luaran penelitian yang telah dihasilkan : :

- Repair of rigid Pavement using Micro Concrete Repair telah Publikasi di ICRMCE 2018 dipublikasi di **Matec Web conferences** 195 01014 (2018) **terindeks Scopus**
- ***Telah dipresentasikan pada*** : The 2 nd Sriwijaya International conference on Engineering, Science and Technology-SICEST , Palembang 15 th-16 th October **" Mechanical Properties of Concrete Which Incorporates Polypropylene Plastic Waste and High-Density Polyethylene " terindeks Scopus**
- ***Diterima dan akan dipresentasikan*** pada **International Conference on Application Technology and Engineering** Nov 22-23 2018 in Jakarta, Indonesia. **"The Long-Term Effects of Nano silica on Concrete" terindeks scopus**

BAB 6. RENCANA TAHAPAN BERIKUTNYA

Rencana Tahapan berikutnya :

- Mendaftarkan **paten** Hak Cipta , telah melakukan kunjungan ke KEMENKUMHAM sedang dalam proses dengan mengisi Web WWW.DGIP.GO.ID
- Publikasi paper yang akan di submit ke **ASIAN JOURNAL OF CIVIL ENGINEERING (Q3)** Atau **KSCE Journal of Civil Engineering (impact factor: 0.600) Q3** Paper"**LONG-TERM EFFECTS OF NANO SILICA ON MECHANICAL PROPERTIES AND CONCRETE DURABILITY**

BAB 7. KESIMPULAN DAN SARAN

Kesimpulan :

- Riset ini telah memperlihatkan hasil yang siginifikan dengan proposal yang diajukan.
- Secara umum belum ada hambatan dan kesulitan dalam melakukan kegiatan riset.
- Progres penelitian telah mencapai 100% (selesai)

Saran

- Prosentase pencairan dana yang disetujui yang terlalu sedikit/kecil dari dana yang diajukan, cukup menyulitkan peneliti

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ICRMCE 2018

Repair of rigid pavement using micro concrete material

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Abstract. Rapid setting materials, especially for concrete repairs made on major arteries such as toll roads which must withstand heavy traffic. Several manufacturers of construction chemicals have been producing various types of rapid setting materials designed for use in repairing such toll roads. However, the existing toll road repair materials have not demonstrated satisfactory performance when applied in the field. This study modified micro concrete materials by adding Polycarboxylate Ether (PCE) and Polypropylene Fiber (PPF) at the time of mixing existing rapid setting materials. It then tested flow tests and setting time at 16, 20, 30, 40, and 60 minutes, as well as compressive strength; and flexural strength tests at the ageing times of 3 hours, 1 day, and 7 days. The concrete micro material was applied directly in the field. The results show that micro concrete material is definitely suitable for toll road repair. The addition of PCE and PPF can increase the flexural strength and modulus of elasticity, meaning that the material is not easily cracked under the repeated strains of heavy traffic loads. Therefore, the use of this micro concrete material has been proven to be viable for future repairs of heavily trafficked toll roads.

1 Introduction

In Indonesia, new toll roads are being constructed rapidly and existing arteries are increasingly being expanded. However, once toll roads are built they often undergo structural damages, such as the Cipularang toll road which connects Jakarta to Bandung. The Cipularang toll road carries heavy traffic and a high volume of vehicles. Contours of the highway that climb sharply and turn abruptly, combined with unstable base soil factors and high amounts of rainfall, result in rapid erosion and other soil issues that cause damage to the road bed and pavement surfaces, including collapsing, pumping, and spalling, as illustrated in the following photos. One of the main obstacles to performing effective repairs is the requirement that these important highways should not be closed for very long during the repair process.

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Fig. 1. Damage to the rigid pavement.

In addition, although high-early-strength cementitious repair materials are commercially available, many of these materials are especially vulnerable to cracking, poor bonding, and premature deterioration, which result from various causes such as incompatibility with the existing concrete pavement [1,2].

Satisfactory repair work requires materials with rapid setting criteria that have high compressive strength and flexure strength. These important characteristics ensure longer service life. Long service life means fewer future repairs as well as longer intervals between rehabilitation and reconstruction projects, leading to significant savings in both the quantity of pavement materials required and overall expenditures [3]. Some studies have shown there have been issues arising when using high-early-strength concrete in repair applications for pavements [4,5]. Therefore, it is essential that good-quality local materials that have the structural capabilities to conform to, or even exceed, the standard criteria for such repairs, should be developed as quickly as possible [6,7,8,9].

Polypropylene Fiber (PPF), shown in Figure 1, is a synthetic fiber with low density, fine diameter and low modulus of elasticity. It exhibits special characteristics such as high strength, high ductility, and durability. Polypropylene Fiber also demonstrates excellent bonding capabilities which can greatly improve the properties of mortar [10].

Fig. 2. Polypropylene Fiber.

This research developed micro concrete material in accordance with the criteria needed for effective repair work in the rigid pavement. This development was accomplished by adding superplasticizer and Polypropylene Fiber (PPF) to existing commercially available repair materials.

2 Materials and methods

Two types of materials were utilized in this research: Estopatch RSP and Patchroc RSP. Estopatch RSP is supplied by Estop Indonesia Corporation, and Patchroc RSP is supplied by Fosroc Indonesia Corporation [11]. Both types of materials are fast-setting micro concrete, and are readily available commercial products. The fiber used, Polypropylene Fiber (PPF) supplied by Sika Indonesia Corporation, has the following properties: fiber length 12 mm; diameter 18 microns; tensile strength 300-400 MPa; elastic modulus 6000-9000 N/mm2; specific gravity 0.91 g/cm3. The superplasticizer used is Polycarboxylate Ether (PCE), supplied by John Hi-Tech Contrindo Corporation.

The mix proportions of each specimen are shown in Table 1. Specimen A0 is Estopatch RSP material; A1 is A0 plus 50 grams PPF (0.2% x A0), and A2 is A0 plus 50 grams PPF (0.2% xA0) and 0.25 litres superplasticizer PCE (1% x A0). Specimen B0 is Patchroc RSP; B1 is B0 plus 50 grams PPF (0.2% x B0) and B2 is B0 plus 50 grams PPF (0.2% xB0) and 0.25 litres superplasticizer PCE (1% x B0).

Table 1. Mix proportions of specimen.

Mix Proportions	Specimen					
	A0	**A1**	**A2**	**B0**	**B1**	**B2**
Binder (kg)	25	25	25	25	25	25
Water/binder	0.15	0.15	0.15	0.15	0.15	0.15
PPF (gram)	-	50	50	-	50	50
PCE (litre)	-	-	0.25	-	-	0.25

A compressive strength test of 50 x 50 x 50 mm cubes in accordance with ASTM C39 for concrete ages of 3 hours, 1 day and 7 days was recorded. Flexural testing of 50 x 50 x 30 mm prisms or beams in accordance with ASTM C78 / C78M-18 [12] were measured at ages of 3 hours and 1 day, while the initial setting time was recorded based on ASTM C403 / C 403-99 [13].

Fig. 2. Test equipment for specimens.

3 Results and discussion

3.1 Setting time

The result of the time setting test is shown in Figure 3. Material B0 sets faster compared to material A0. These results indicate that both materials are rapid setting, because they can harden in less than 60 minutes. Setting time is an important factor for cost-effective rigid pavement repairs, because reducing total work time (and highway usage down time) is critical when major highways are involved. Setting time also indicates when, and how easily, a particular type of material can be applied. Significantly, including PPF in the concrete mixture does not have obvious negative effects on the setting times for either material, A0 and B0.

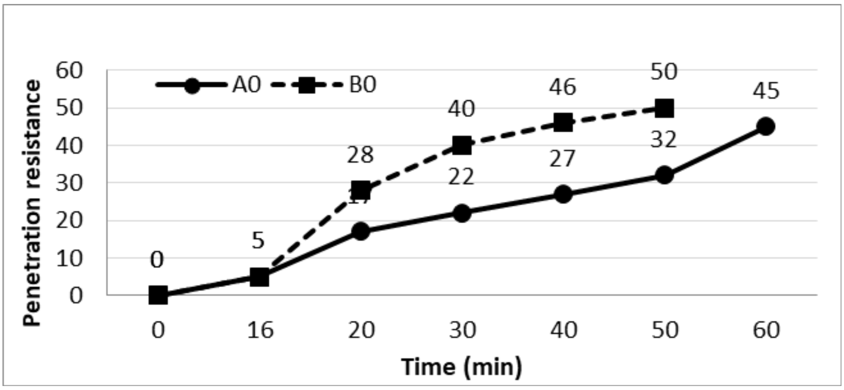

Fig. 3. Result of setting time test.

3.2 Compressive strength

The results of the compressive strength tests are shown in Figure 4. Significant improvements occurred with the addition of PPF as well as the addition of PPF and Admixture. At the age of 3 hours for A0: 22.2 MPa, A1: 23.1 MPa there is an increase of 4%, while for A2 of 24.3 MPa there is a 9.5% increase. For B1 specimens at 3 h, there was an increase of B0: 21.9 MPa to 22.9 MPa, 4.5% increase; B2 increased by 15% to 25.2 MPa. At the age of 1 day, on specimens A1 and A2 compressive strength increased by 2.9% and 24.3% respectively. As for B1 and B2, compression strength increased by 13.5% and 35.5%. 7-day age specimens exhibited an increase in compressive strength for A1 of 0.9%; A2 of 11.2%; B2 of 1.4%; and B2 of 9.9%. Based on the results of the compressive strength test, the addition of PPF and admixture can increase the compressive strength by11.2% and 9.9%. This result is in line with previous research that states that adding polypropylene fibers to mortar can increase compressive strength and reduce plastic shrinkage cracks [14].

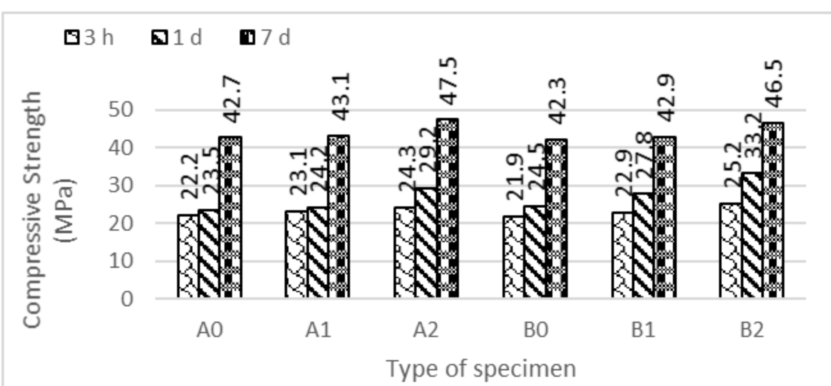

Fig. 4. Result of testing the compressive strength.

This enhancement may stem from improvements in the mechanical bond strength as the introduction of the ductile, durable fibers enable the concrete material to delay micro-crack formation and even arrest their propagation afterwards to a certain extent [15]. Additionally, empirical evidence shows that the addition of superplasticizer can improve the workability of HPC due to the presence of PCE nanoparticles in the concrete slurry, which can fill any cavities within the concrete and thus result in strengthening of the bonds between the components of the mixture. [16].

Moreover, the use of fibers in the mortar or concrete can significantly enhance the bond strength between the old substrate and the new repair materials, which is one of the most important requirements for a successful repair [17].

3.2 Flexural strength

The flexural strength test results are shown in Figure 5. At an age of 3 hours, flexural strength in sample A0 is 3.1 MPa, which increased by 9.7% to 3.4 MPa in specimen A1. A2 increased by 22.6% to 3.8 MPa. Although for specimen B1 there is an increase of 12.5 MPa (B0: 3.2 MPa, B1: 3.6 MPa), for B2 there is an even larger increase of 25% to 4 MPa. At the age of 1 day, an increase of 58.3% was recorded. A0: 3.6 MPa; A1: 5.7 MPa; A2: 6.9 MPa (an increase of 91.7%). Specimen A0 at 7 days was 7.1 MPa; A1: 8.7 MPa (22.5%) and A2: 10.3 MPa (an increase of 18.4%). Then at 7 days, specimen B0 was recorded at 7.2 MPa; B1: 8.6 MPa (19.4%); B2: 10.4 MPa (44.4%).

The flexural test results show the addition of PPF and the effective admixture can improve the flexural strength in materials A0 and B0. This shows both A0 and B0 materials can be used as repair materials for rigid pavement roads, and the quality of the repairs would improve even more if combined with PPF and admixture.

As a further benefit, adding polypropylene fibers to the cement composites is also an effective method of preventing crack formation [18]. The short polypropylene fibers, when distributed uniformly throughout the entire volume of concrete, act to sew the edges of cracks together and restrict any further propagation [19]. Obviously, reduction of cracking is of great importance, especially in the first hours after pouring before the concrete reaches its full strength [20].

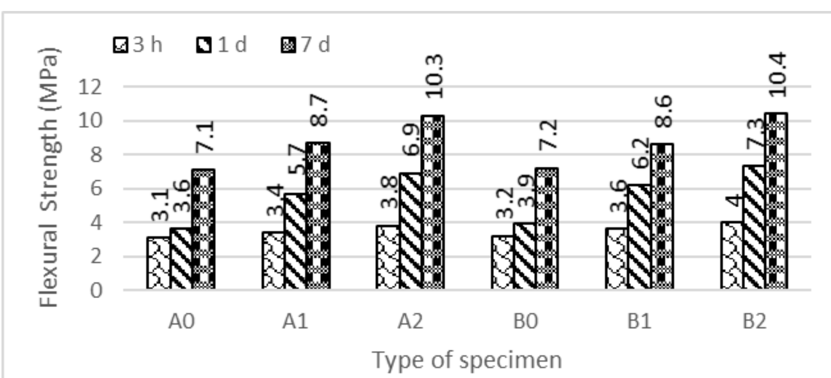

Fig. 5. Result of testing the flexural strength.

4 Conclusions

1. The use of either Polypropylene Fiber (PPF) or Polypropylene (PCE) is highly effective to improve the compressive strength and flexural strength of concrete mixtures used in repairing heavily trafficked road surfaces such as toll roads.

2. Adding PPF and PCE significantly improves the compressive strength by 11.2% and the flexural strength by 18.4% for material A0, and increases the compressive strength by 18.4% and flexural strength by 44.4% for material B0

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Mechanical properties of polypropylene plastic waste usage and high-density polyethylene on concrete

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Abstract. Utilizing plastic waste as a construction material is one of the techniques used to overcome the problems associated with environmental pollution caused by the indiscriminate dumping of plastic wastes. It is refined into aggregates that are used as a fractional replacement for coarse aggregates in concrete mixtures. The sole objective of this research work is to analyze the use of plastic wastes in concrete. Two types of aggregates extracted from plastic wastes, namely Polypropylene (PP) and High-Density Polyethylene (HDPE) were used in carrying out this study. The percentages of PP used were 5%, 10%, and 15%, while the percentages of HDPE used were 15%, 20%, and 25%. Similarly, the slump value, compressive strength, and tensile strength were tested for 28 days and at concrete ages of 3 and 7 days. The results obtained proved that a percentage increase in plastic aggregate would invariably reduce the value of slump, compressive strength, and tensile strength. The optimum percentage of PP and HDPE used were 10% and 15% respectively. This research contributed providing an alternative to overcoming plastic wastes.

1. Introduction

The increasing production of plastic waste has become one of the major factors of environmental pollution and a serious problem which we must overcome. The fact that plastic is non-biodegradable constitute a danger to the surroundings. The innovation of converting plastic wastes into useful materials is very vital and needs to be applied, such as using it to replace coarse aggregates in concrete.

High-Density Polyethylene (HDPE) and Polypropylene (PP) are examples of plastics that are used on a daily basis. Polypropylene is characterized by a high tensile strength and Young Modulus and has a density between 0.900 g / cm3 and 0.915 g / cm3 and molecular relationship [1,2]. High Density Polyethylene (HDPE) is a form of plastic with a density of 0.940 g / cm3 - 0.965 g / cm3 and a strong molecular relationship [3].

A recent study has revealed that the use of HDPE and PP wastes as materials in road construction is capable of improving the strength of the typical asphalt binders as one of the different ways of utilizing plastic wastes [4]. Polypropylene, which is used as a synthetic fiber has the ability to increase the density of concrete [5]. HDPE waste processed into additional 25% fine aggregate can be utilized in concrete mixtures, and it has a potential for minimizing natural aggregate usage [6].

The study revealed that the use of PET type plastic waste as fine and coarse aggregate in a concrete mixture has both positive and negative effects. Although it cannot be used all alone as concrete, it can make concrete to be more durable [7].

This study carries out an analysis of the mechanical properties of High-Density Polyethylene (HDPE) and Polypropylene (PP) types of plastic wastes as a partial replacement for rough aggregates in concrete mixtures.

2. Methodology

Plastic waste such as polypropylene (PP) and High-Density Polyethylene (HDPE) indicated in Fig.1, have been incorporated into plastic pellets by waste processing company in Bantar Gebang, Jakarta.

(a)
(b)

Figure 1. Plastic Seeds (a) Polyethylene (PP), (b) High-Density Polyethylene (HDPE)

Cement OPC Type 1 coarse aggregate, fine aggregate obtained from PT Adhimix Precast Indonesia.

Table 1. Proportion of mixtures per m3 for fc 25 MPa

Material	Code						
	B0	**PP1**	**PP2**	**PP3**	**PE1**	**PE2**	**PE3**
Cement (Kg)	486	486	486	486	486	486	486
Fine Aggregatee (Kg)	603	603	603	603	603	603	603
Coarse Aggregatee (Kg)	1121	1064,9	1008,9	952,8	946,9	896,8	840,8
Plastic (Kg)	0	56,1	112,1	168,2	167,1	224,2	280,2
Water (Liter)	170	170	170	170	170	170	170

In the mixture proportion shown in Table 1, B0 is a concrete specimen without a mixture of plastic waste (reference concrete). PP1 is a specimen obtained by replacing 5% of the coarse aggregate weight with polypropylene (PP) waste. PP2 and PP3 are specimens obtained by replacing 10% and 15% of the coarse aggregate with polypropylene (PP) waste respectively. PE1, PE2, and PE3 are specimens obtained by replacing 15%, 20%, and 25% of coarse aggregate with the plastic waste of High-Density Polyethylene (HDPE) respectively. Figure 2 shows the manufacture of specimens and curing.

Figure 2. Manufacture of specimens and curing

The tests carried out on slump that use ASTM C 143-90 standard is shown in Fig. 3. Compressive strength testing was carried out in accordance with ASTM C39 and tensile strength is termed ASTM C496 / C496M [8,9]. The compressive strength testing of the specimen was carried out in a cylinder which has a height of 20 cm and 10 cm diameter. The compressive and tensile strength tests were performed at concrete ages 3, 7 and 28 days. The number of specimens is 63 pieces.

(a) (b) (c)

Figure 3. Slump test (a), compressive strength (b) and (c) Tensile strength

3. Results and discussion

3.1. Slump test

Figure 4 indicates the slump value for specimens containing plastic waste, which is lower than the standard concrete slump value (B0: 12.5 cm). This indicates that workability reduces when a certain percentages of both plastic wastes are incorporated [10,11]. The slump values for PP1, PP2, and PP3 are 8.5 cm, 6.5 cm, and 6 cm respectively, while PE1, PE2, and PE3 have slump values of 7.5 cm, 4.8 cm, and 2 cm respectively. PP1, PP2, PP3 have higher slump values compared to PE1, PE2, and PE3.

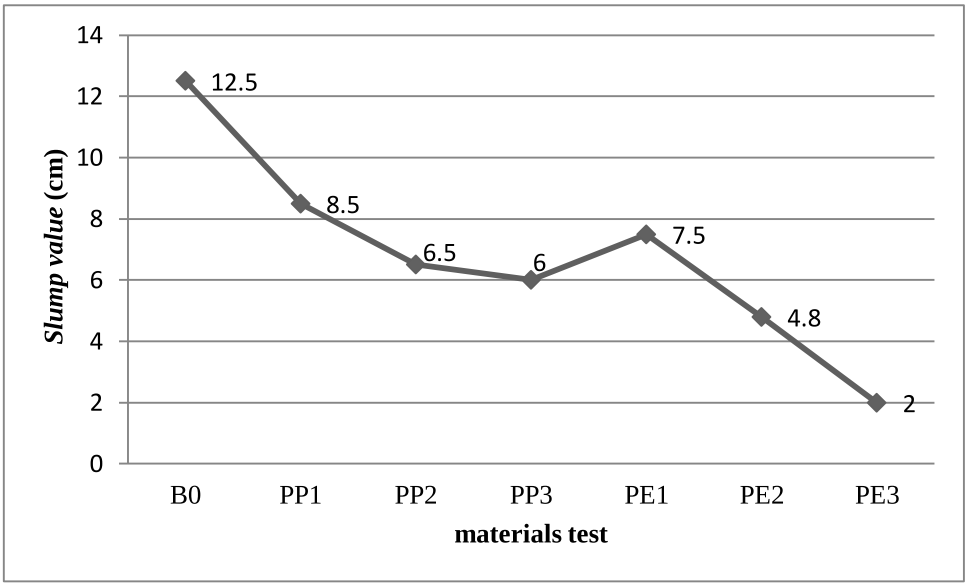

Figure 4. Slump test result

The reduction in slump value is due to lack of uniformity in the shape of plastic particles which result in low fluidity. The decrease in the value of slump can be checked by using superplasticizer as has done by Rai et al. [11].

3.2. Compressive strength

Figure 5 reveals the value of concrete compressive strength at the ages of 3, 7 and 28 days. At the age of 3 days, PP1 and PP2 were greater than B0 with the values 109% and 105% respectively. While the PP3 value was 79% of B0. PE1, PE2, and PE3 at 3 days reached 96%, 76% and 73% of B0 respectively. At the age of 7 days, PP1, PP2, PP3 values had become 102%, 93%, 86% of B0 respectively. In specimens PE1, PE2, and PE3, the values reached 100%, 65%, and 58% respectively. Achievements recorded at 28 days of concrete age by PP1, PP2 and PP3 were 86%, 85% and 79% of reference concrete respectively, while the specimens PE1, PE2, and PE3 had values 100%, 58%, and 51% respectively.

The inclusion of plastic reduces the value in concrete compressive strength. This is in line with the previous research which stated that there is a reduction in adhesive strength between cement paste and plastic surfaces as the plastic particles become bigger in size [11,12]. The concrete compressive strength of PE1, PE2, and PE3 has lower values compared to PP1, PP2, and PP3. This is due to the fact that HDPE has a shiny and smooth surface which makes it difficult to adhere to other materials in the concrete [3]. To overcome this problem of no adhesion, the polymer type styrene modified rubber and superplasticizer were used [13].

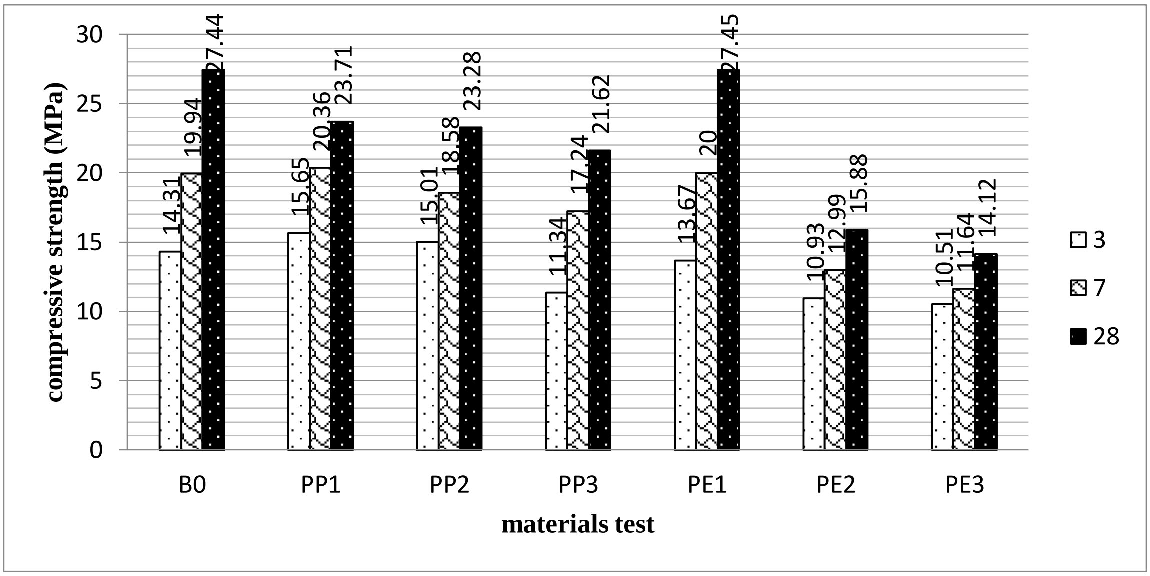

Figure 5. Result of compressive strength test

3.3. Tensile Strength

The results of tensile strength tests are shown in Fig. 6. The concrete tensile strengths of PP1, PP2, and PP3 in the age of three days were 118%, 85% and 82% of reference concrete respectively. The percentages of tensile strength PE1, PE2 and PE3 are 113%, 101%, and 76% of B0 respectively. At the age of 7 days, the tensile strength for PP1 was 98%, PP2 was 91% and PP3 was 70%. Specimens of PE1, PE2, and PE3 had tensile strength values of 85%, 74%, and 60% respectively. At the age of 28 days, the tensile strength of specimens PP1 was 82%, PP2 was 76% and PP3 was 77%. The values of PE1, PE2, and PE3 were 70%, 61% and 50% of B0 respectively.

Decrease in tensile strength occurred when the percentages of plastic waste decreased. It happened as a result of lower aggregate between cement paste and plastic waste It is also partly due to the lower Interfacial Transition Zone (ITZ) of plastic waste [10].

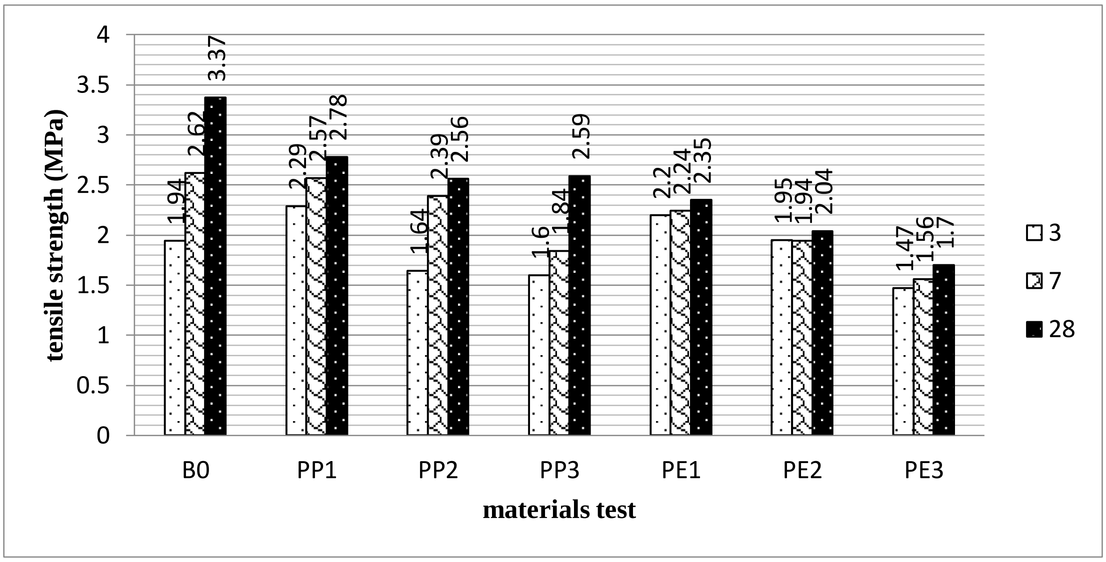

Figure 6. Result of tensile strength test

4. Conclusion

The percentage inclusion of plastic aggregate in a concrete mixture reduces slump value, tensile strength, and compressive strength values. Plastic waste is also used as a replacement for coarse aggregate. The compressive strength of PP with optimal percentage 10% became 85%, while PE 15% became 100% from reference concrete. PP compressive strength rises to 76%, compared to 10% in reference concrete, while rose to 100% from previous 15%. .

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