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“Civil Engineering Innovation for a Sustainable Future”

The 5th Euro Asia Civil Engineering Forum Conference (EACEF5)

Surabaya, Indonesia, 15-18 September 2015

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Antoni

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PREFACE

Papers published in this edition of Procedia Engineering have been presented in The 5th Euro Asia Civil Engineering Forum (EACEF-5) at Petra Christian University, Surabaya, Indonesia, from 15-18 September 2015. The theme for EACEF-5 is **‘Civil Engineering Innovation for a Sustainable Future’**. The conference was jointly organized by Petra Christian University, Surabaya, Universitas Pelita Harapan, Jakarta and Universitas Atma Jaya Yogyakarta, Yogyakarta, Indonesia.

Civil engineers and researchers in the field are challenged to play important roles and responsibilities in constructing a sustainable future. EACEF-5 conference provided a platform for sharing ideas and findings, as well as the challenges involved. Publication of all of the aforementioned papers in Procedia Engineering enables a wider circulation of the valuable thoughts contained in the papers.

The Editors would like to express their highest gratitude to all of the contributing authors of the papers published in this volume, as well as to the Organizing Committee and other parties involved.

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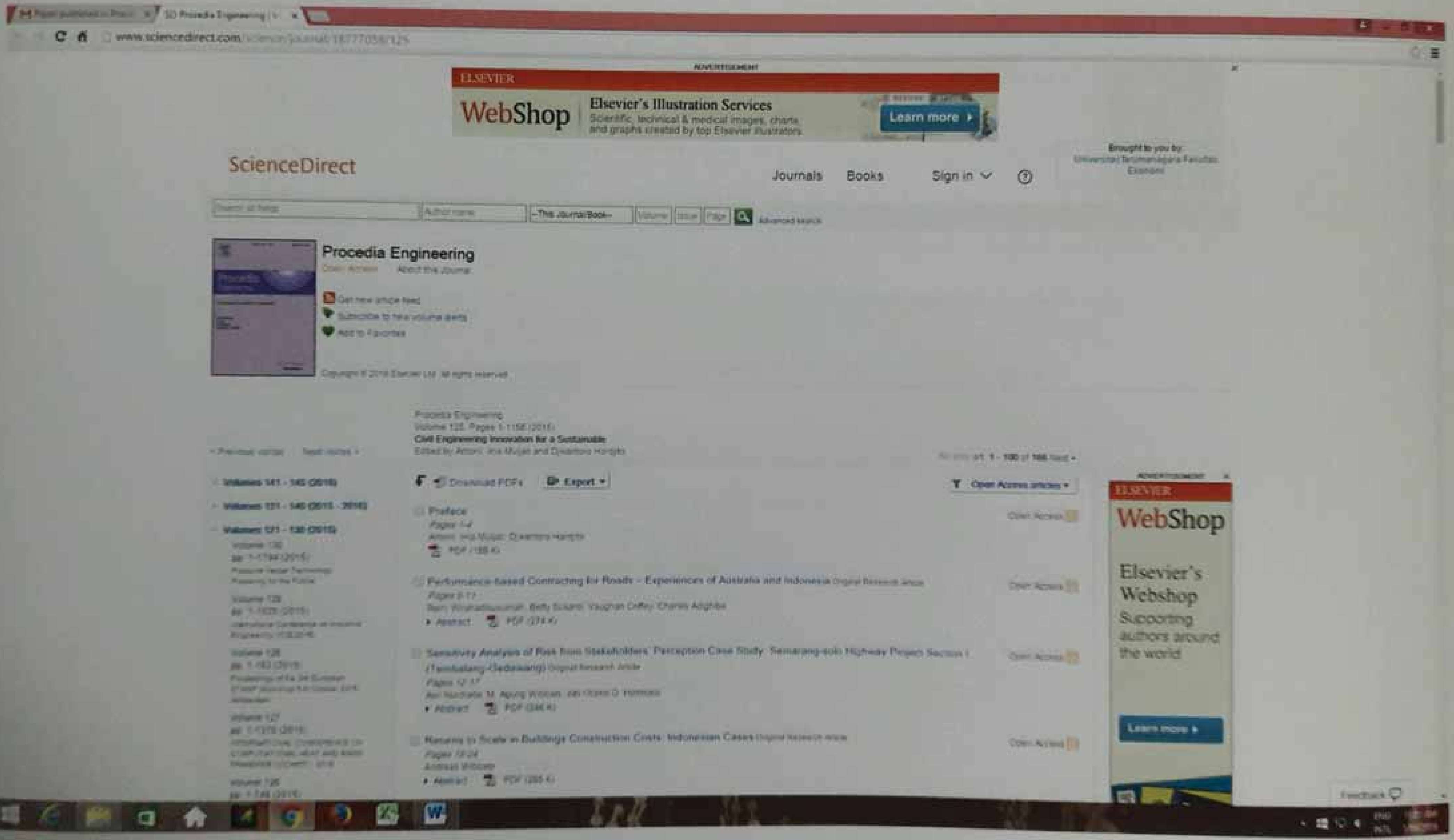

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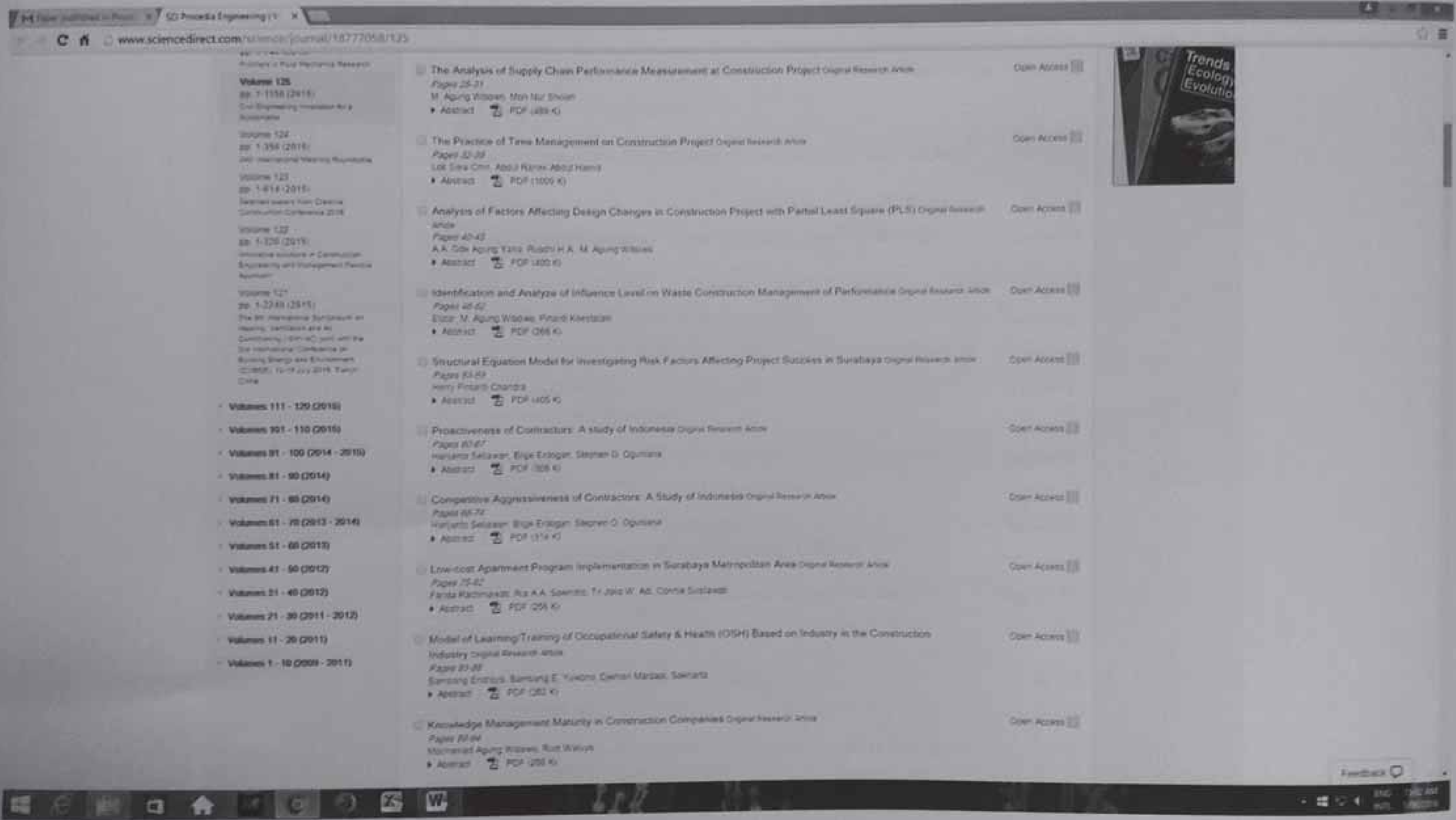

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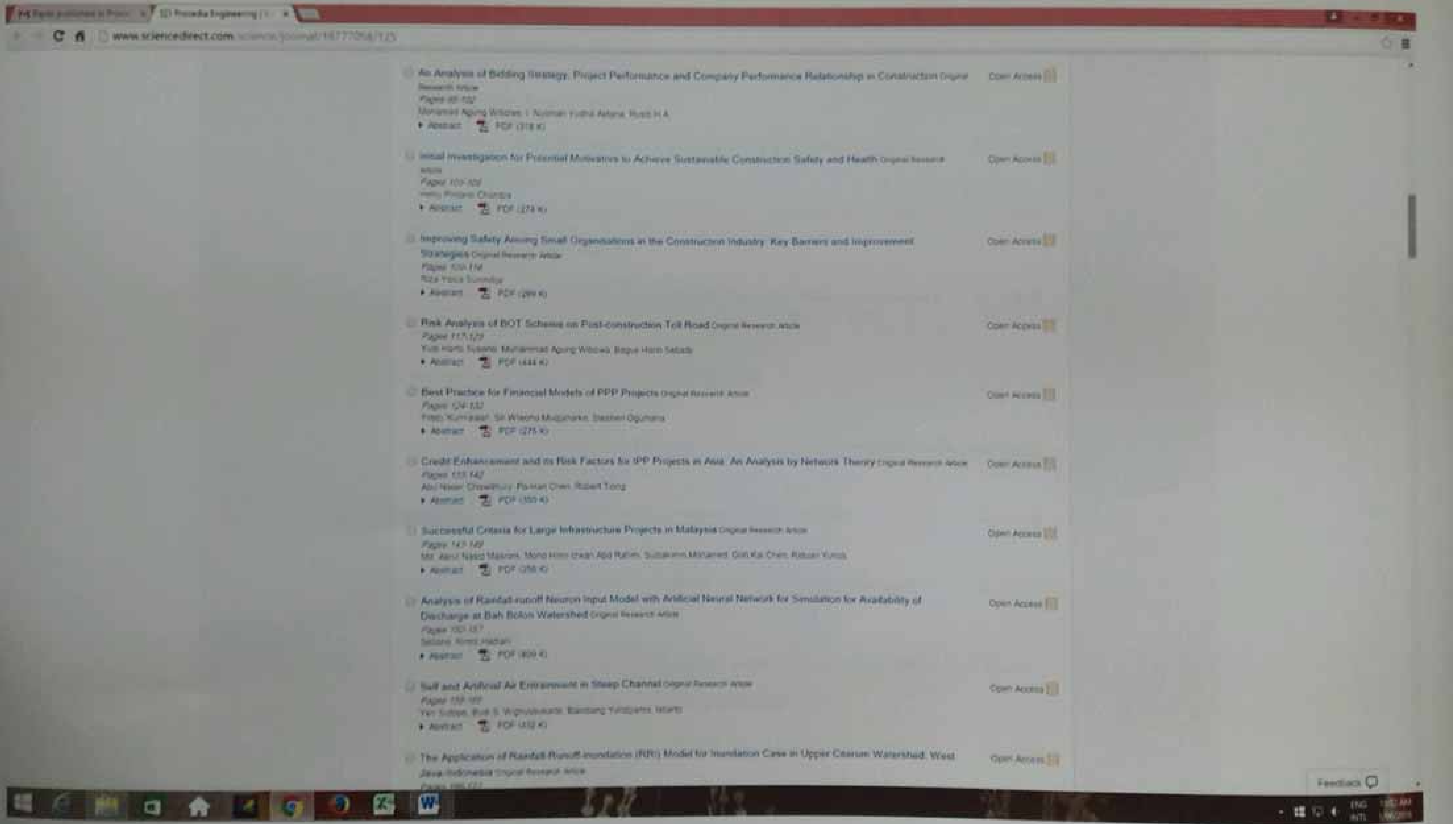

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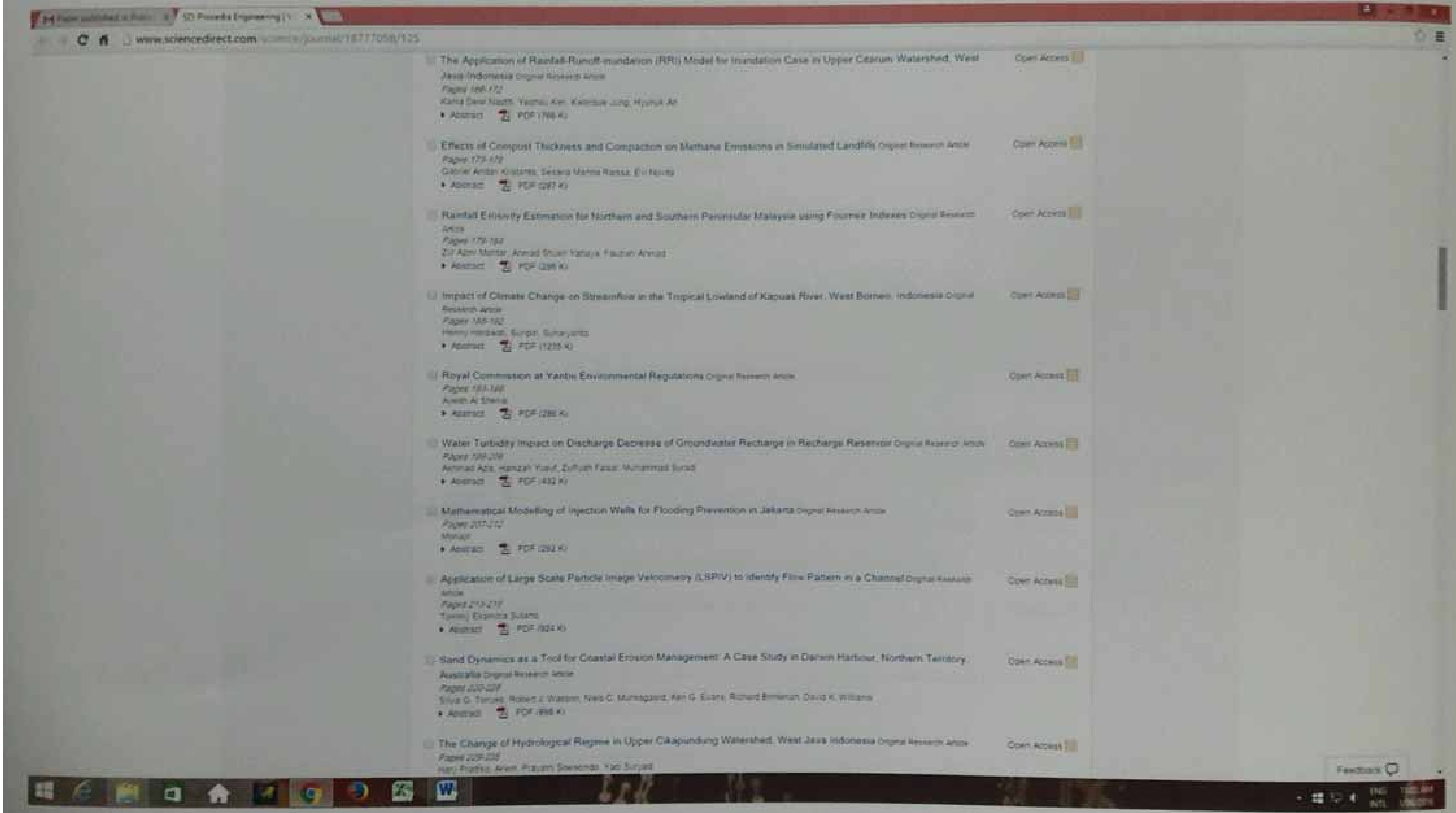

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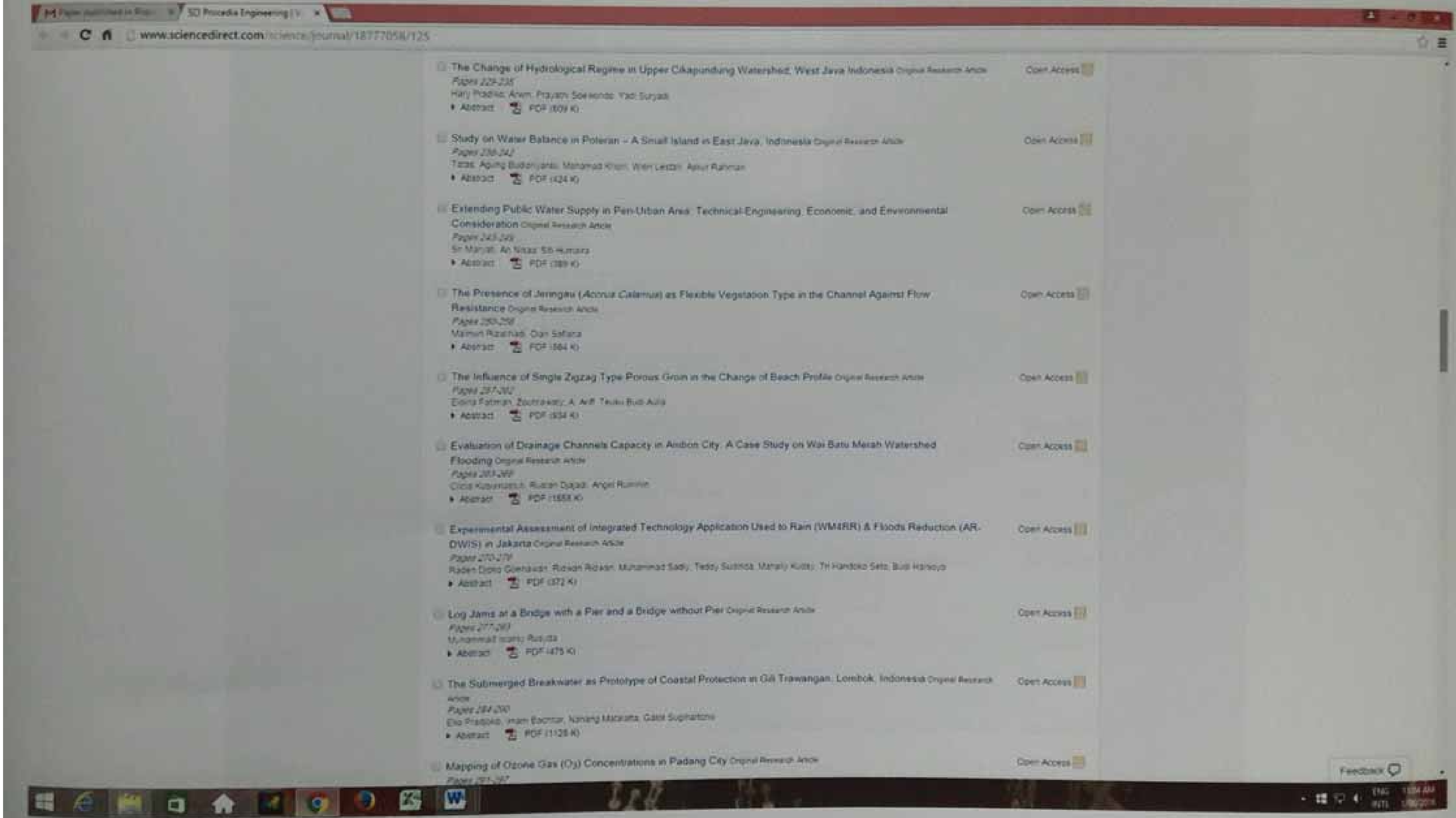

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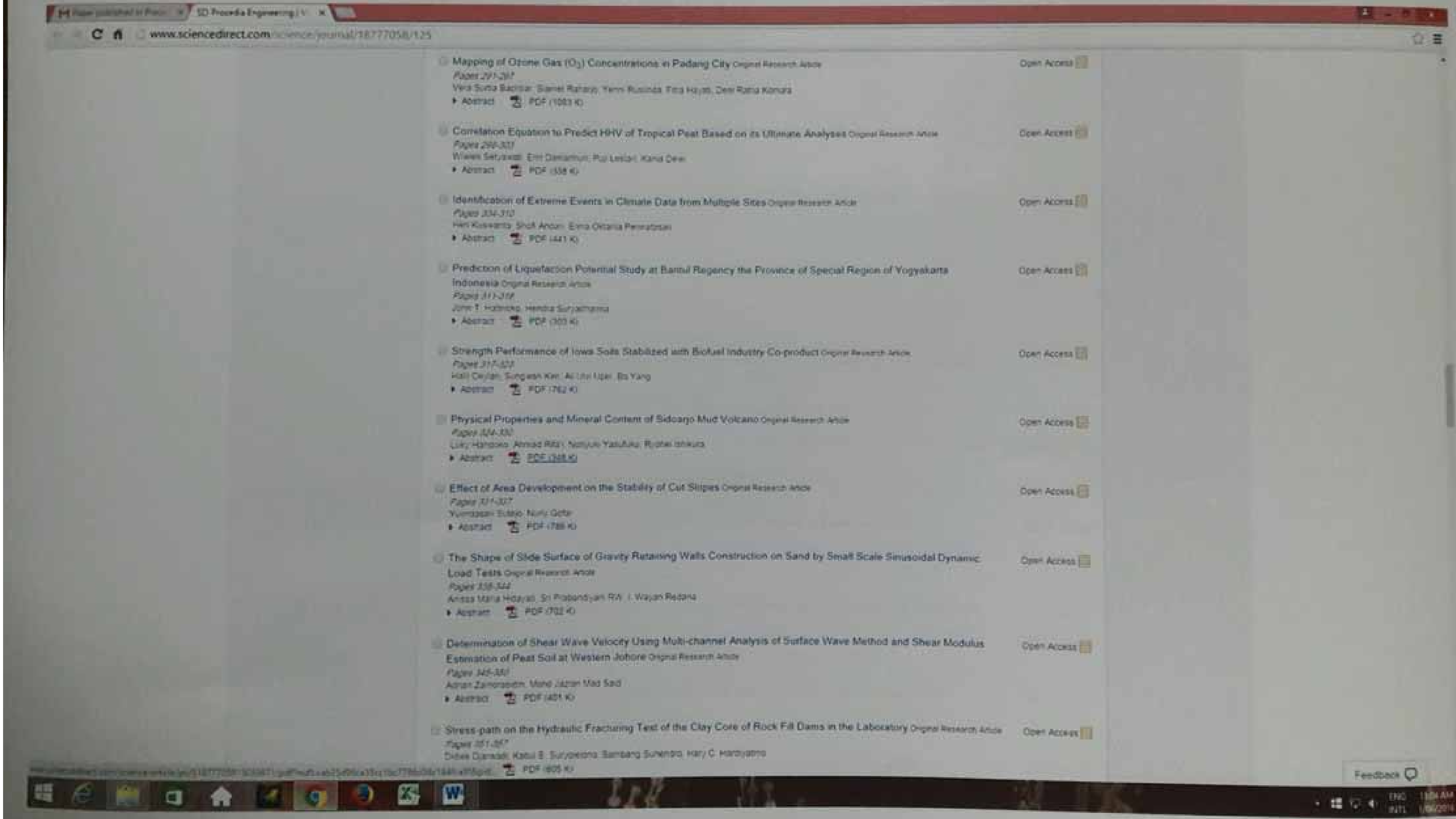

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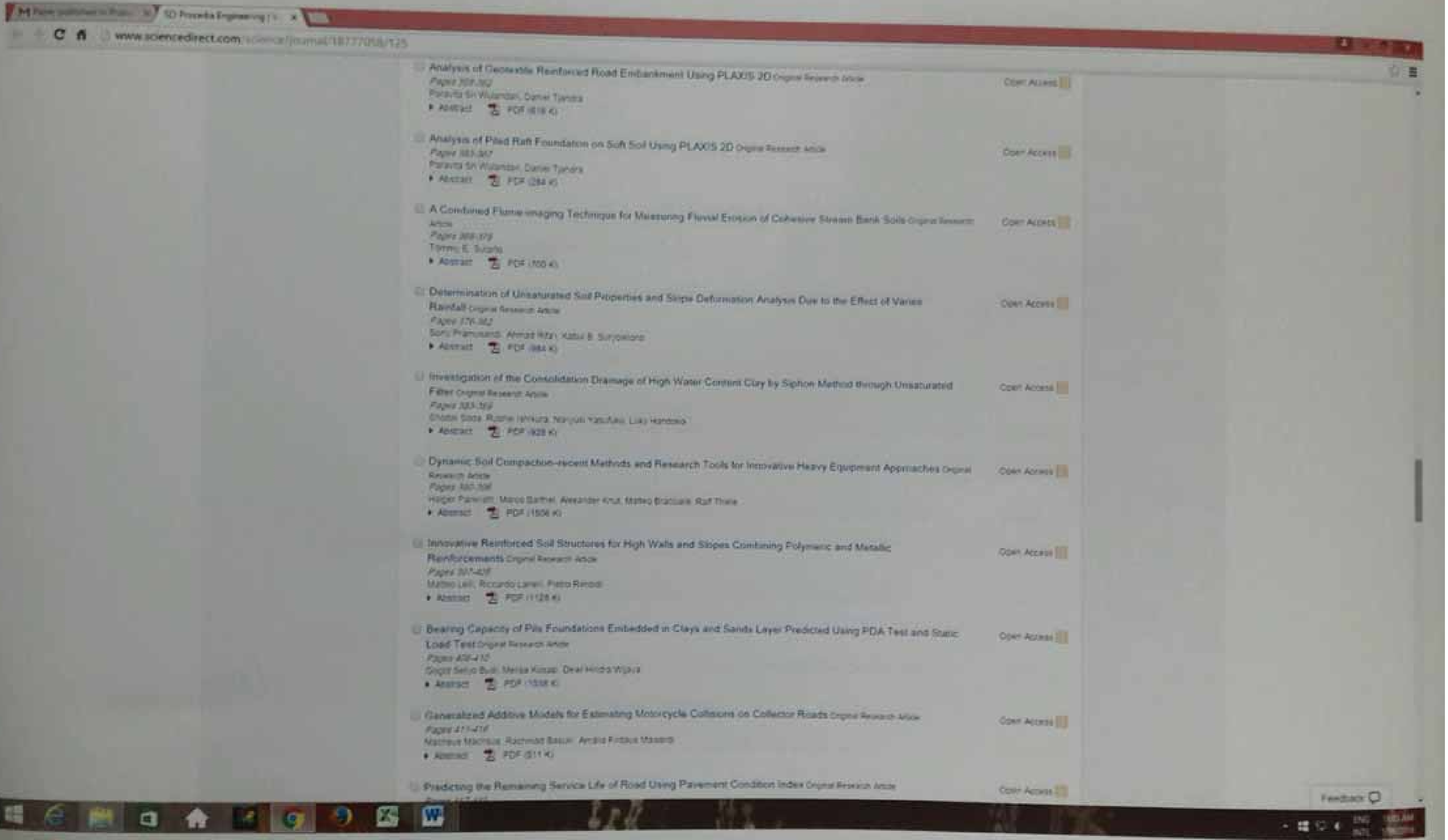

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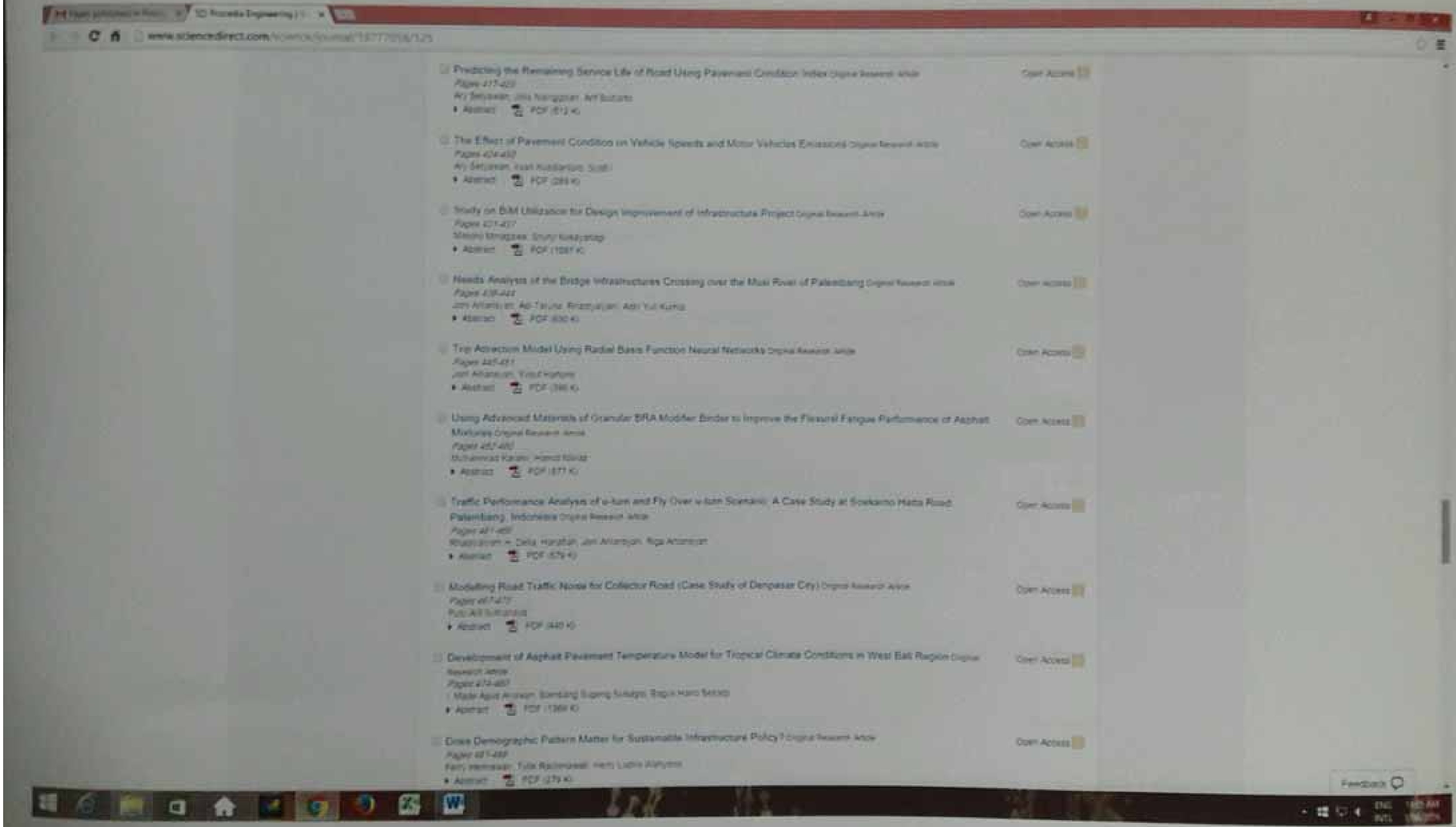

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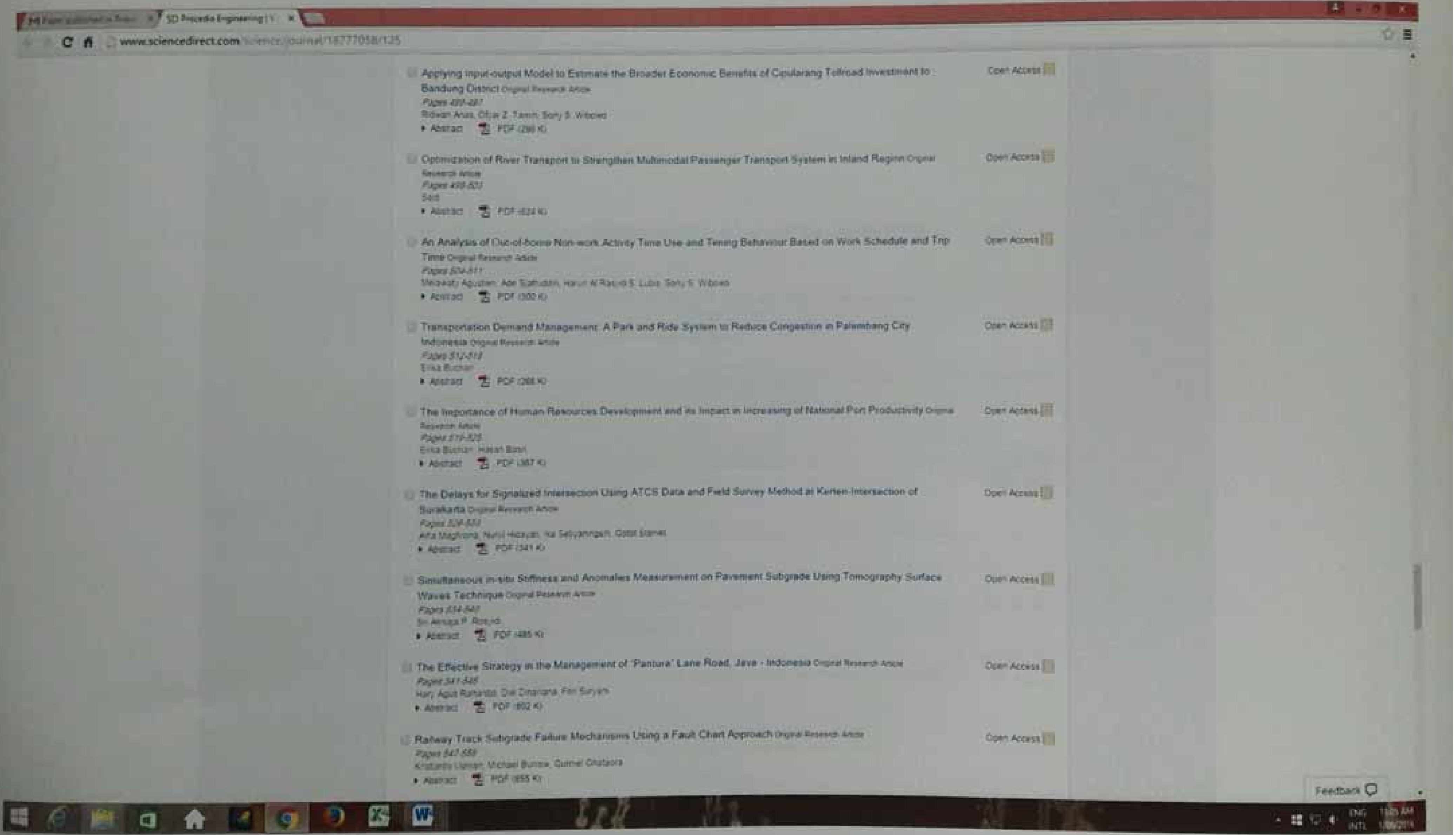

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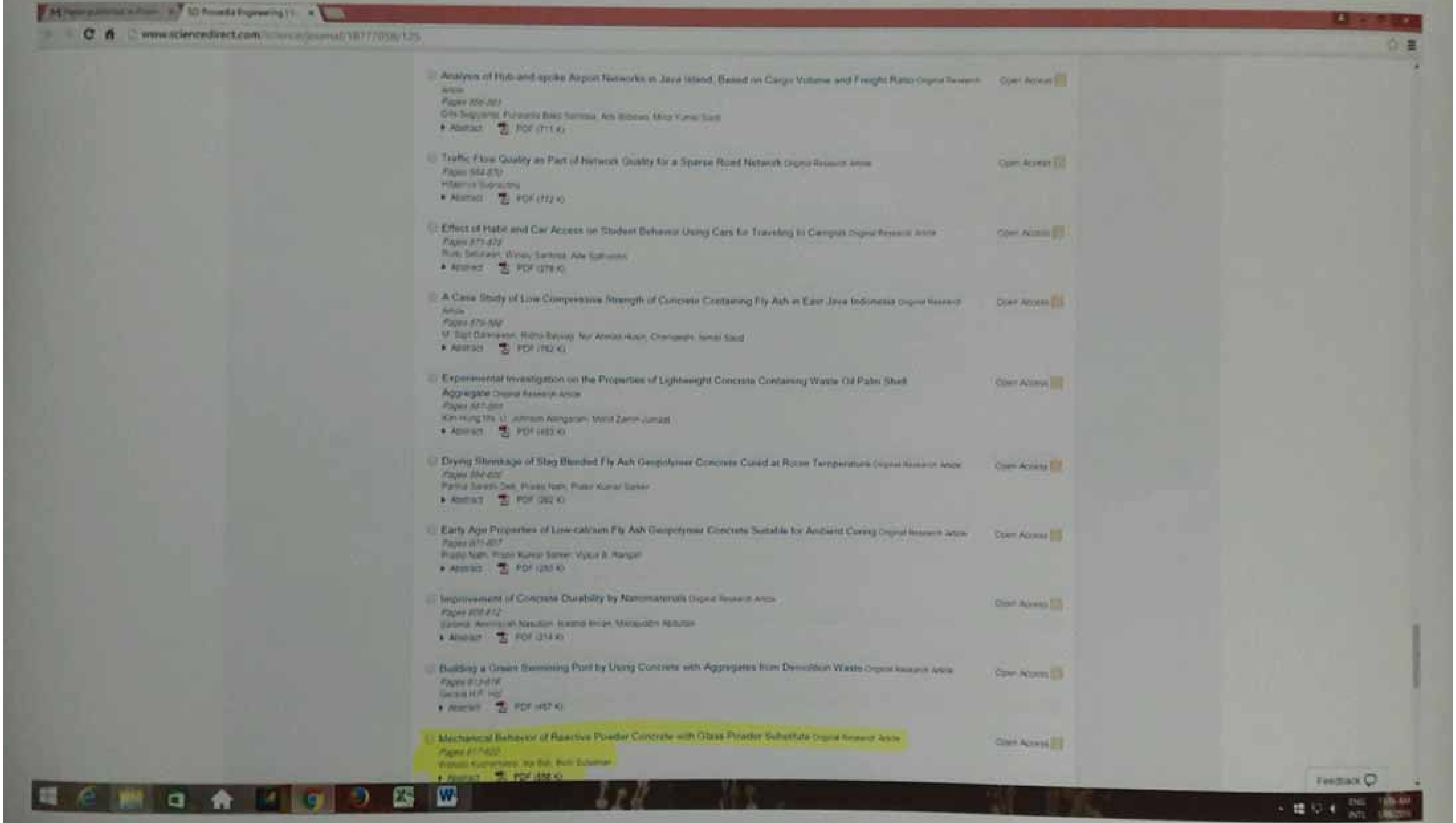

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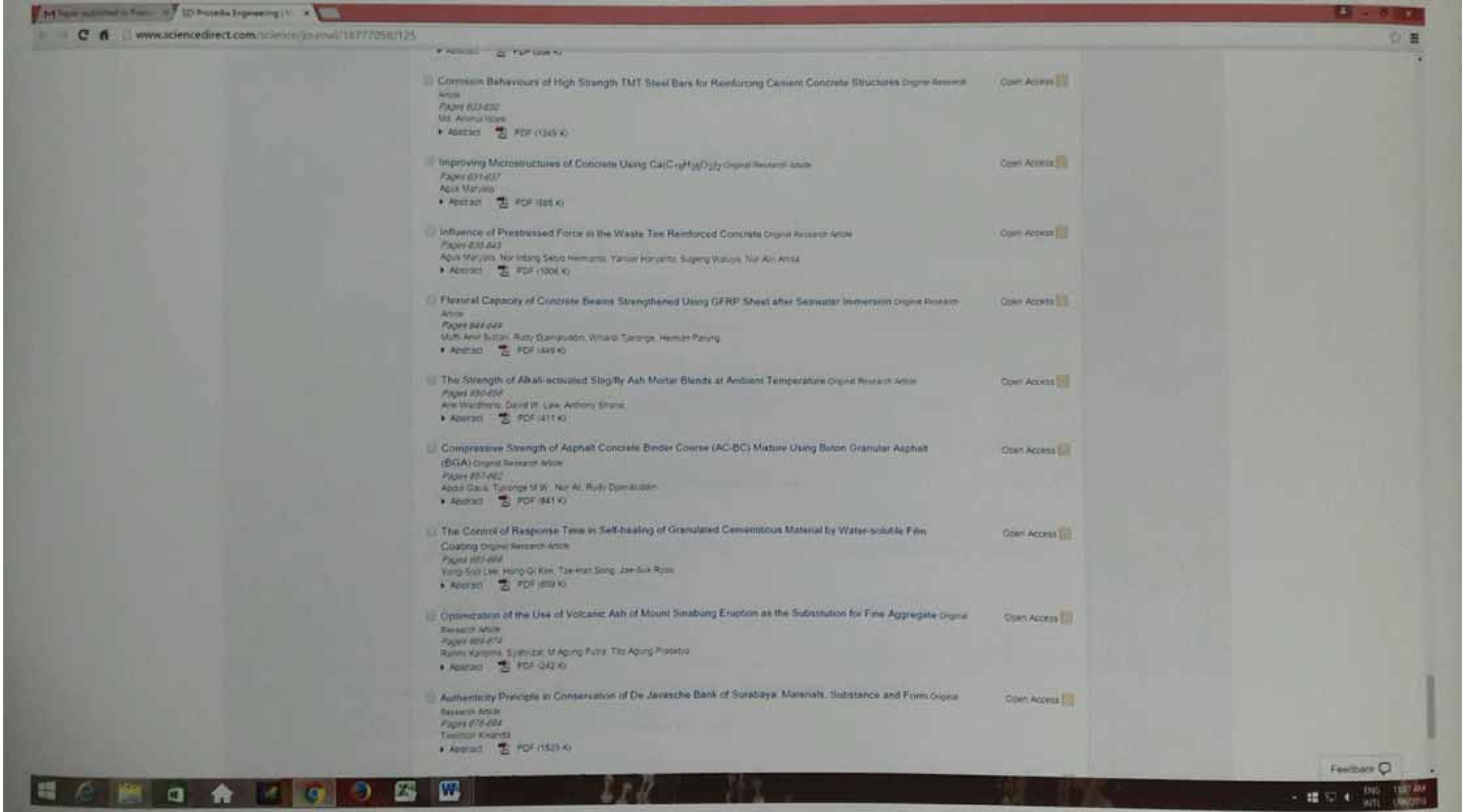

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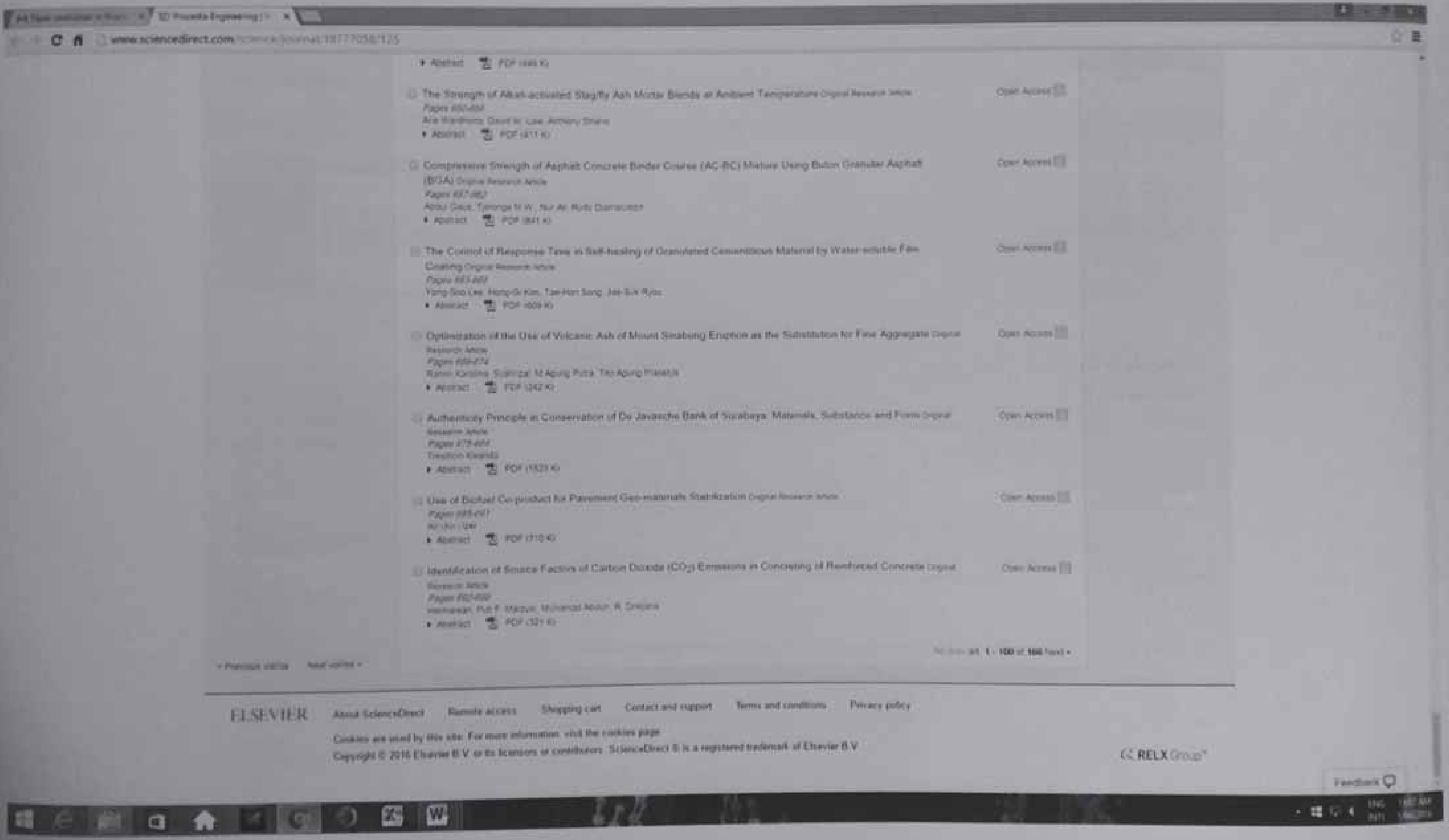

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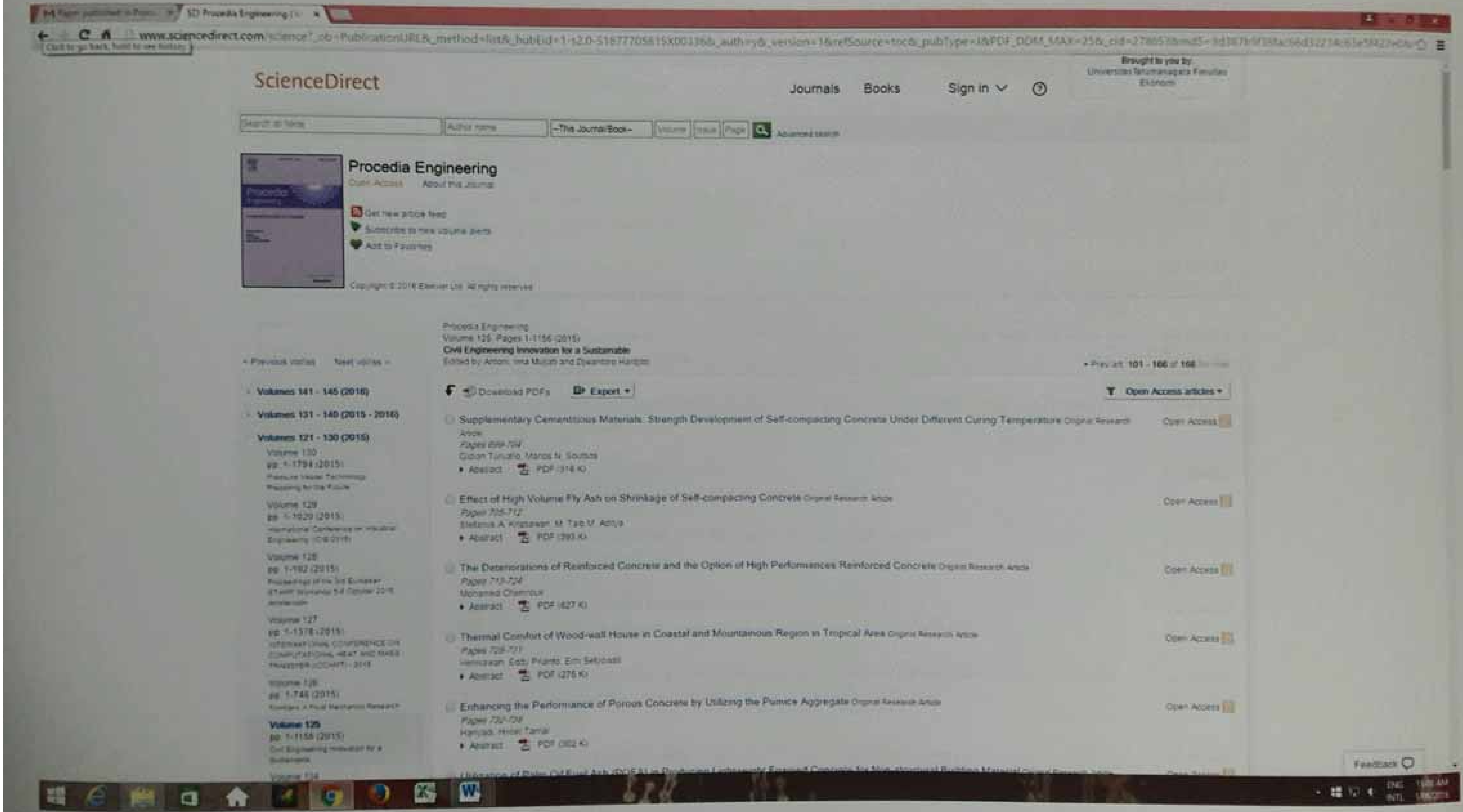

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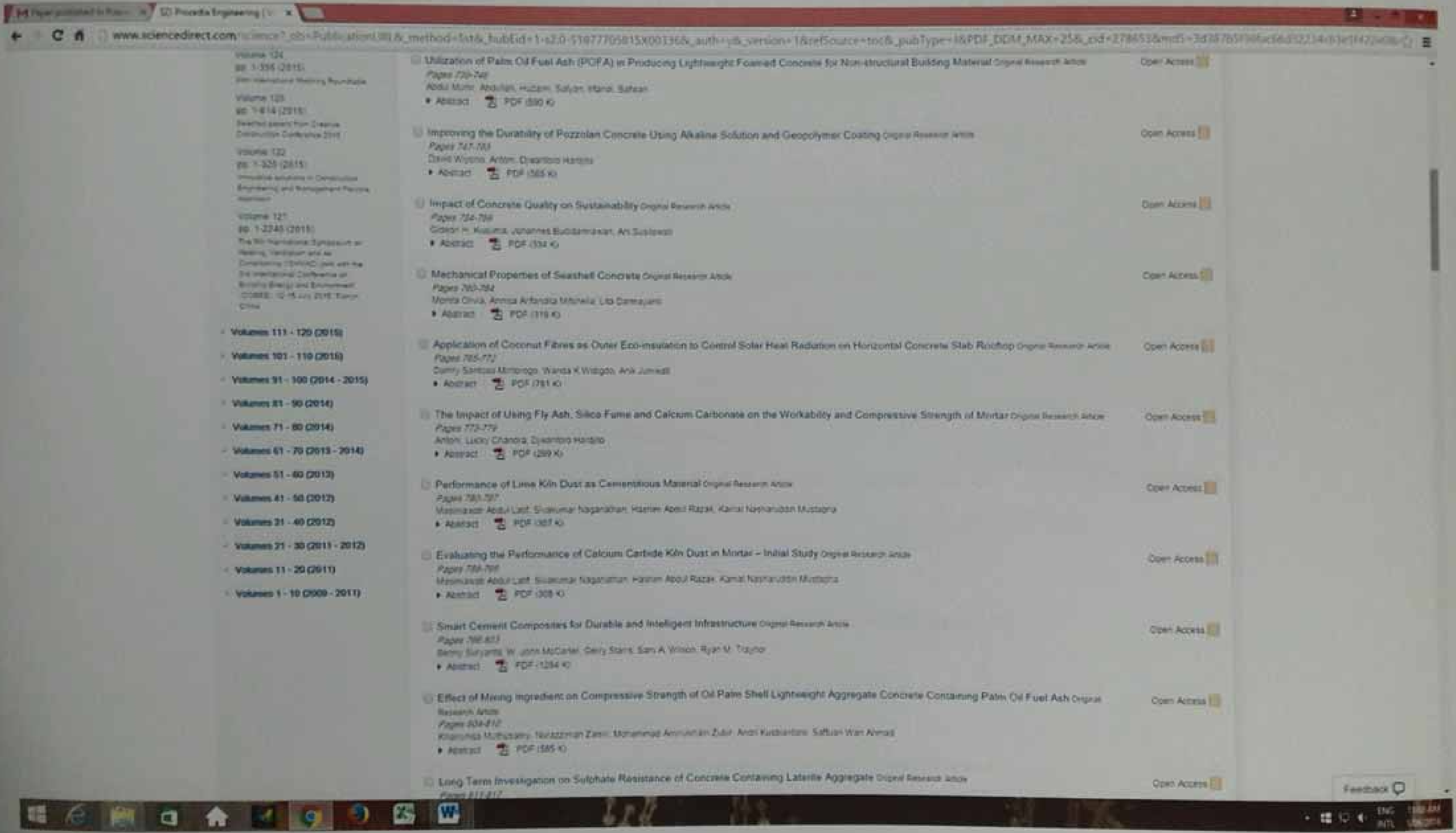

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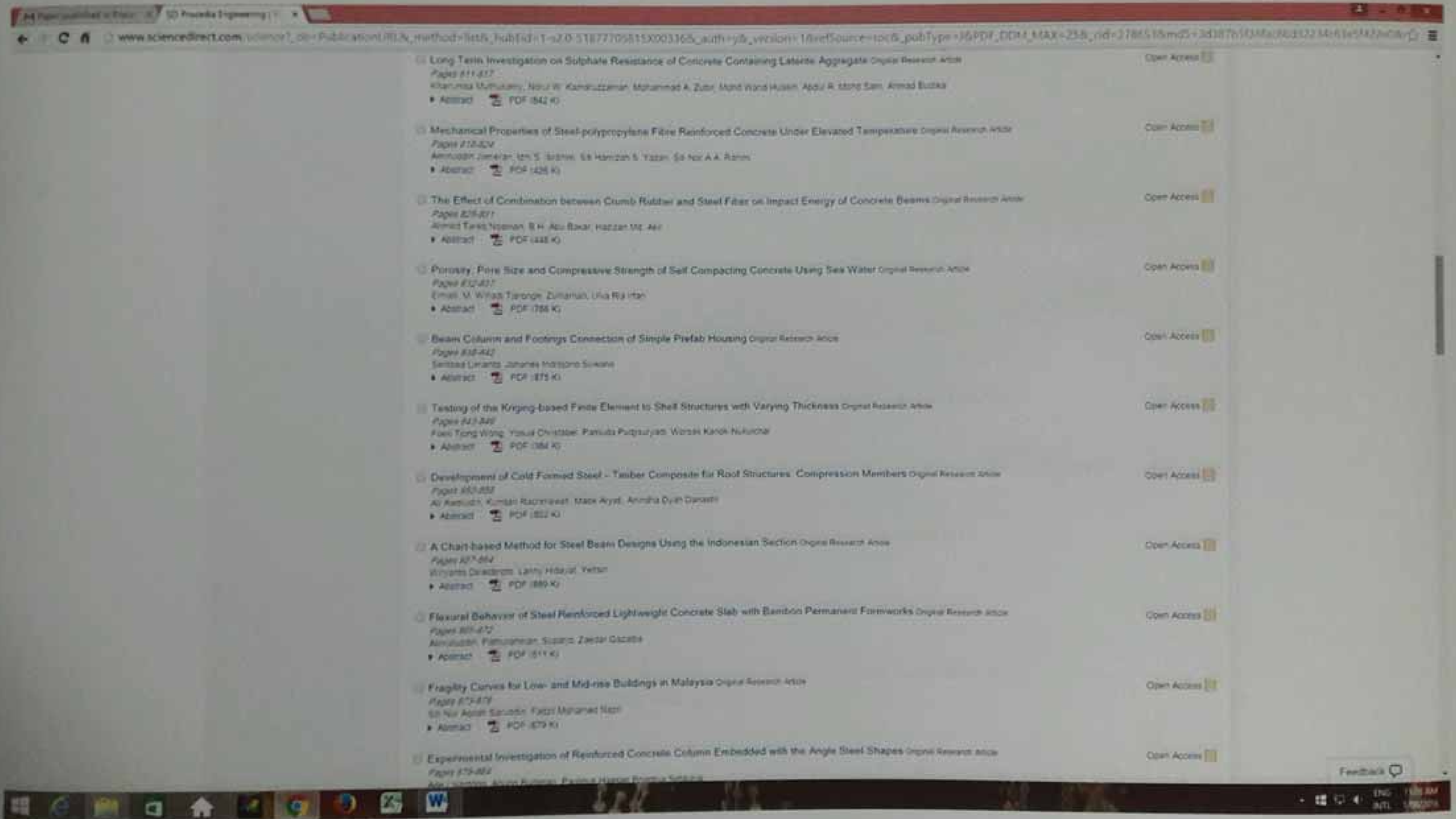

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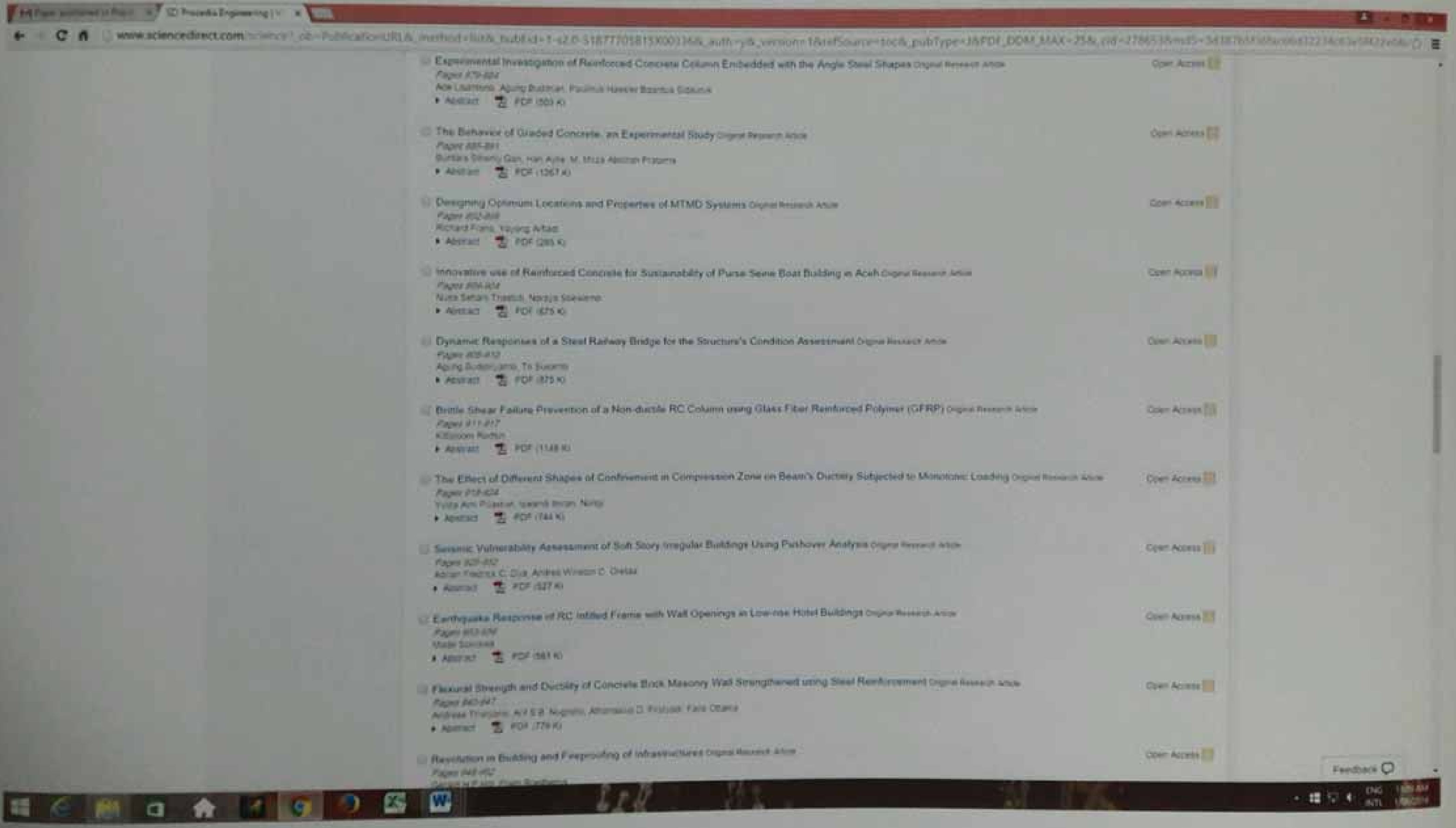

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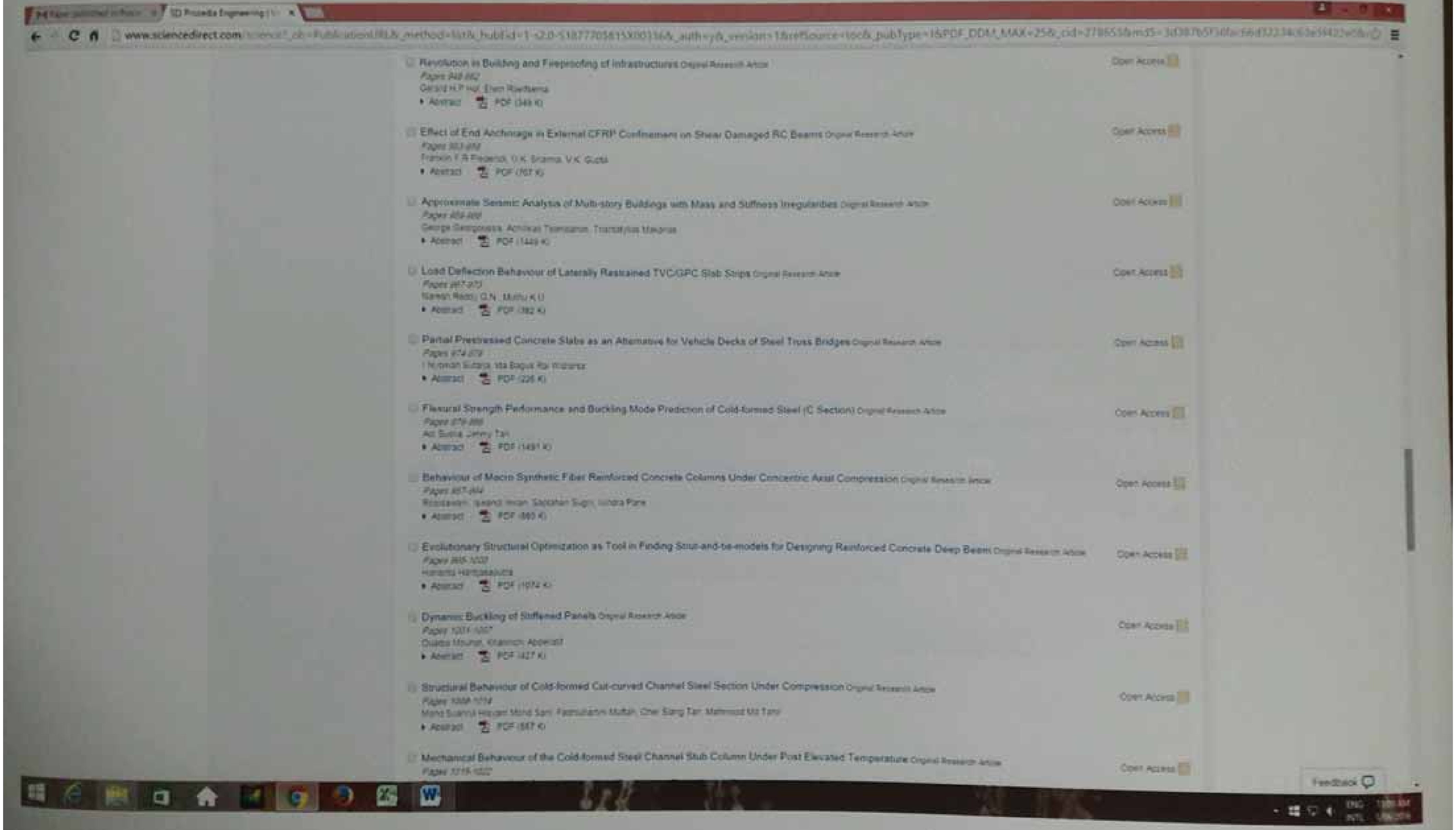

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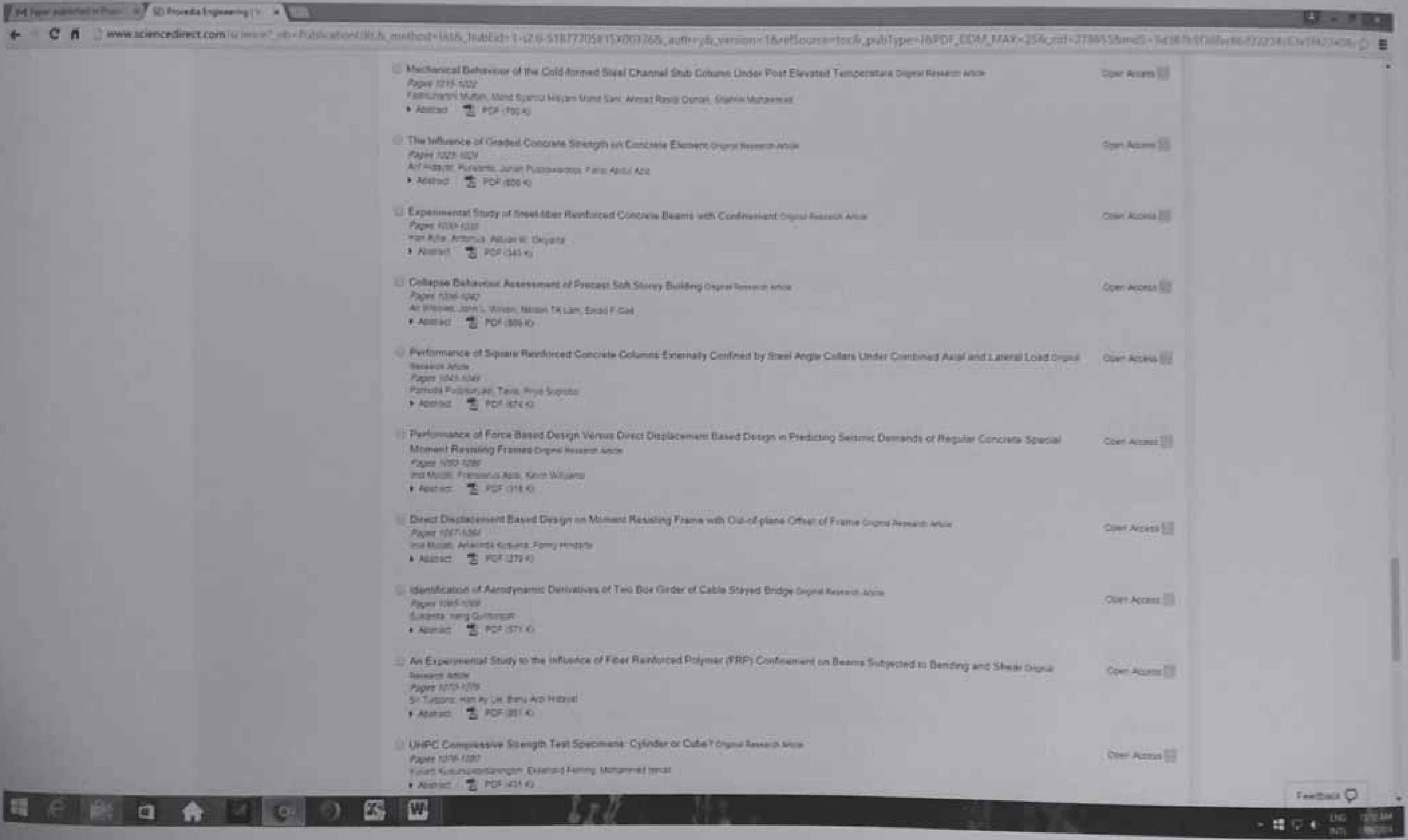

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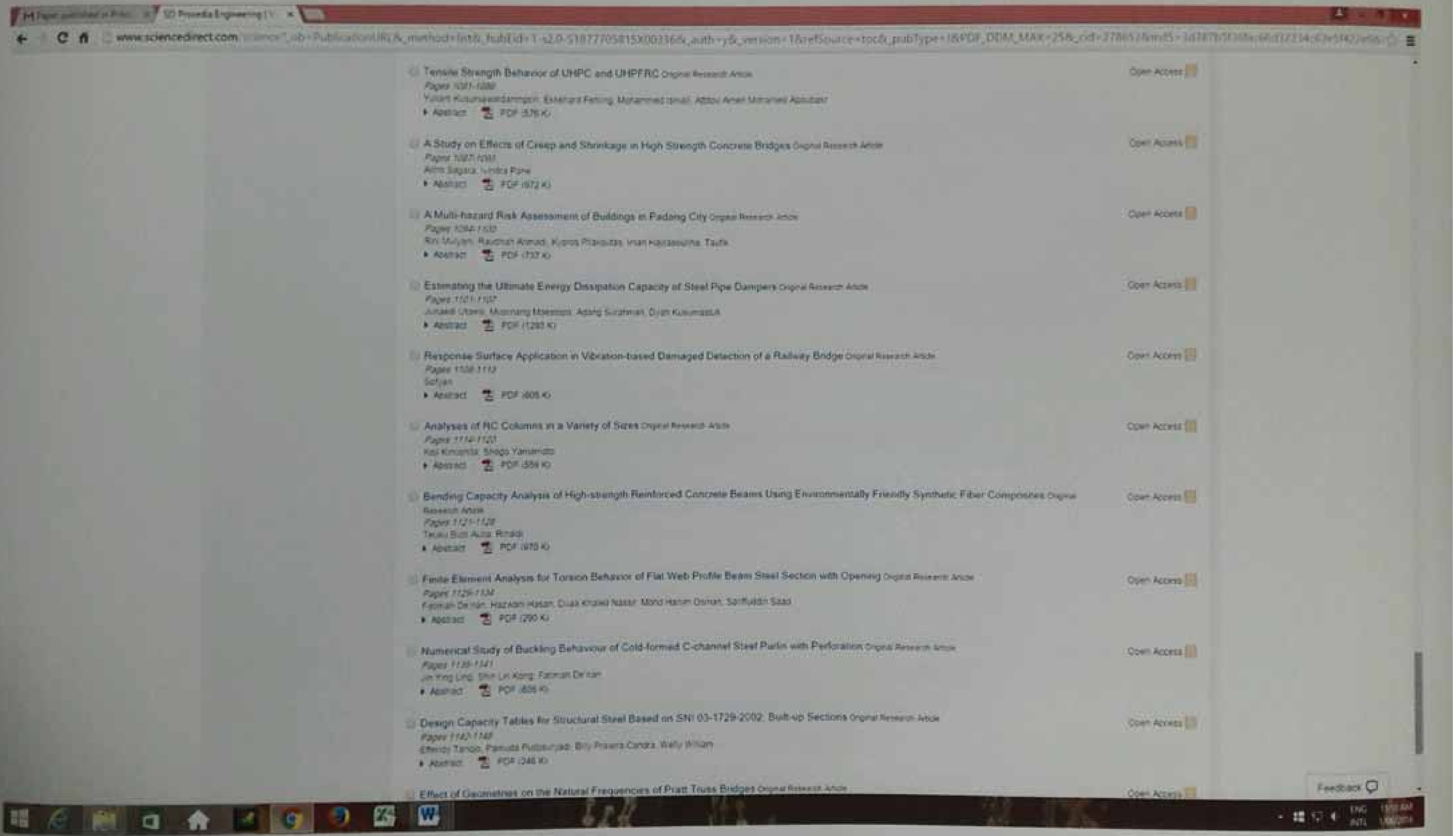

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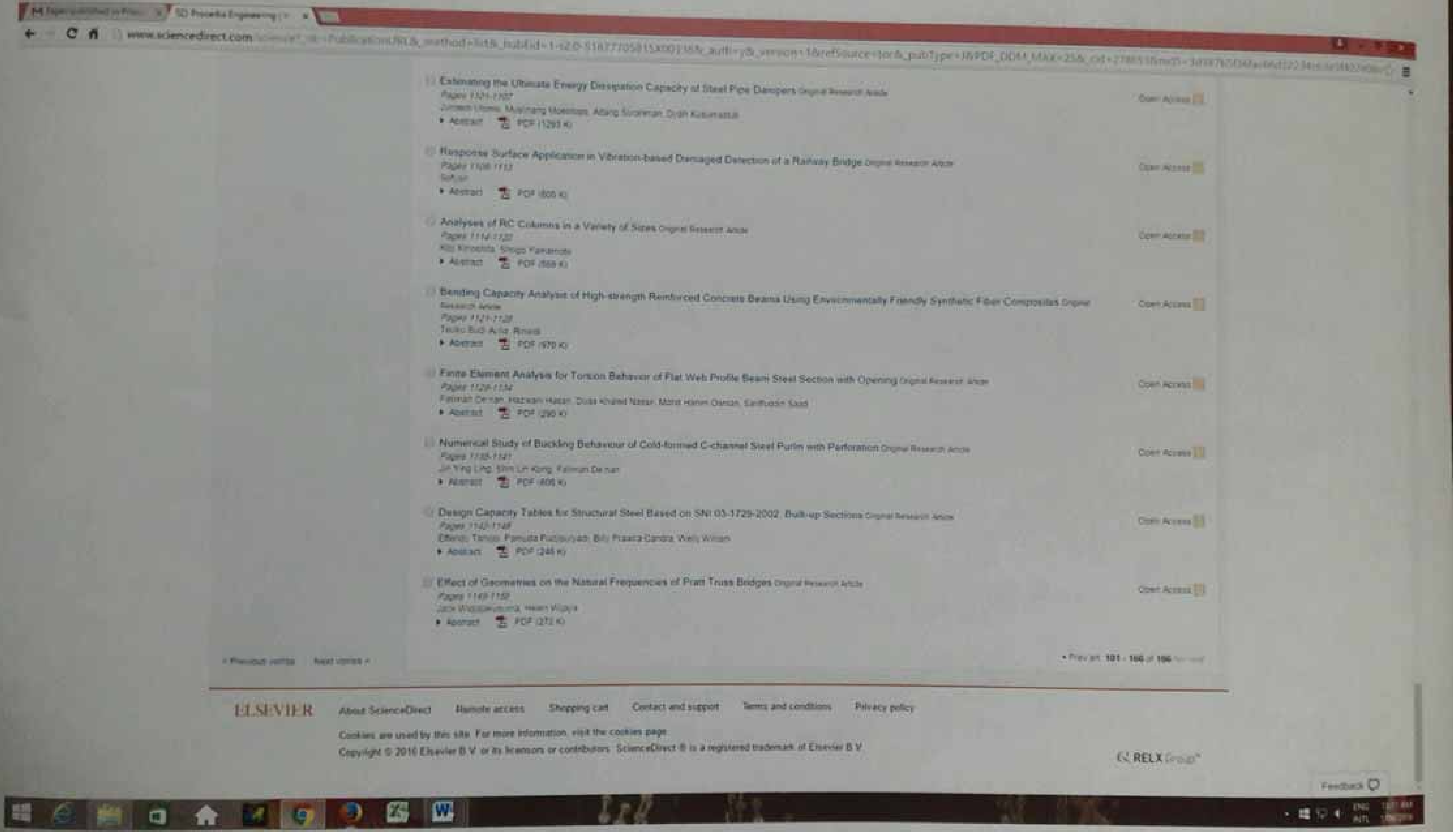

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Mechanical behavior of reactive powder concrete with glass powder substitute

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Abstract

As reported in literature, the Reactive Powder Concrete (RPC) with quartz powder substitute has a high compressive strength of 180 MPa and has a fairly high tensile strength. That research used the RPC with quartz powder to cement ratio of 30% and steam curing technique in an autoclave temperature of 250°C. Concerning the use of local and recycled material, in this study, the quartz powder is substituted by glass powder from the waste glass shards material of housing industry. The objective of this study is to investigate the influence of glass powder in the mechanical behavior of RPC. The mechanical behavior is examined by the tests of compressive strength, flexural strength and split tensile strength. The RPC uses glass powder that grained to micron meter size with the content as much as 10%, 20%, and 30% of cement mass, and the maximum temperature of steam curing is 95°C. The results indicated that the use of glass powder in this study was good enough to replace quartz powder in RPC. The maximum compressive strength value that can be achieved in this study is 136 MPa for the RPC with the glass powder content of 20%.

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Keywords: Reactive Powder Concrete, glass powder, quartz powder, mechanical behavior, compressive strength

1. Introduction

Reactive Powder Concrete (RPC) strength can be characterized on the composition of its constituent materials and calcium-silicate-hydrates (CSH). Stabilization of RPC strength can be done by adding quartz powder as one of the main constituent components. Currently, the RPC with quartz powder to cement ratio of 30% and steam curing

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technique in an autoclave temperature of 250°C, can reach a high compressive strength of 180 MPa and has a fairly high tensile strength [1].

For the substitution of quartz powder in the RPC, the glass particles demonstrated sufficient technical properties, such as compressive strength, flexural strength, and modulus of elasticity. Another advantage, the glass particles has an active pozzolanic material due to the amorphous silica as the glass-making material. When it is mixed with calcium from portlandite ($Ca(OH)_2$), will form a second form of CSH, which improves the properties of concrete [2].

In this study, the objective of introducing the glass powder in the RPC is to verify the improvement of mechanical behavior of RPC such as its compressive strength, flexural strength and split tensile strength. And concerning the use of local and recycled material, glass powder from the waste glass shards material of housing industry is used.

2. Reactive Powder Concrete

Reactive Powder Concrete (RPC) is a concrete made of powder materials that are experiencing a second binding reaction, after binding the water with cement. A comparison of physical, mechanical, and durability data from RPC and HPC (High Performance Concrete) shows that RPC has better strength (both compressive and flexural strength) and have a permeability which is smaller than the HPC.

RPC was developed in 1994 in France as a new category of high strength composite concrete. The RPC has a compressive strength of 120-200 MPa and a flexural strength of 30-60 MPa. If required, RPC can reach strengths of 200 MPa with apply special conditions, such as high temperature treatment and external pressures before and when setting [3]. The RPC is now widely used that is concrete with quartz powder mixture in it. In Indonesia, the supply of quartz powder is limited, therefore the production cost of RPC with quartz powder content is fairly large. In this study, glass powder is proposed to be used as substitution of quartz powder.

According to Bentur and Mindess [4], the addition of fibers into concrete can improve two factors: the strength and toughness or hardness of the composite material. In this RPC, the fiber is used in the form of steel fiber where the goal is to get the optimum value of the compressive strength of concrete. Moreover, the addition of fiber is intended to prevent the occurrence of cracks in the concrete in the area as a result of the tensile loading [5].

Properties comparison between quartz powder and glass powder i.e. the constituent element of quartz is SiO_2 (silicon dioxide), while glass is made of silica, soda ash (Na_2CO_3), and limestone ($CaCO_3$ or $MgCO_3$). The hardeness level of quartz and glass (a type of glass used for glass windows) are 7 of mohs scale and 5.5 of mohs scale, respectively. Based on its formation, quartz is formed naturally (igneous) and the glass is formed by manufacturing process. If compared with quartz powder, glass powder is a material that has properties almost like quartz powder itself.

3. Methodology

The RPC in this study uses glass powder from the waste glass shards material that grained to micron meter size with the content as much as 10%, 20%, and 30% of cement mass. The gradation of glass powder used consisted of 0.075 mm size as much as 20%,0.150 mm size by 35%, and 0.250 mm size by 45%. Proportion of mix design of RPC with glass powder content of 10%, 20%, and 30% can be seen in Table 1. The main materials are used included PPC (Portland Pozzolana Cement), water, glass powder, silica fume, superplasticizer (type F), silica sand (0.3-0.5 mm), and steel fiber.

For the curing procedure, the specimens with age of 1 day are removed from concrete molds and soaked in a tub filled with water for 3 days, then the steam process is carried out for 10-12 hours in sealed vat with temperature of 95°C. After the specimens have concrete age of 14 days, the test of specimens are conducted in order to get the compressive strength, flexural strength and its split tensile strength.

Table 1. Proportion of mix design[†]

No.	Material	Glass powder content (kg)		
		10%	20%	30%
1	Water	4.008	3.873	3.747
2	Cement (PPC)	20.040	19.365	18.734
3	Silica sand	22.044	21.301	20.607
4	Silica fume	5.010	4.841	4.683
5	Superplaticizer	0.602	0.581	0.562
6	Glass powder	2.004	3.873	5.620
7	Steel fiber (volume of 1.5%)	2.665	2.665	2.665

[†] Volume of 0.023 m^3

4. Results and discussions

The specimens of RPC with the glass powder content of 10%, 20% and 30% consist of 15 cylinder specimens for compressive strength test, 9 cylinder specimens for split tensile strength test, and 6 beam specimens for flexural strength test. The dimension of cylinders is diameter (Ø) of 10 cm and height of 20 cm, and the beams size is 10 cm x 10 cm x 40 cm.

The average of concrete compressive strength test results can be seen from Table 2 and Fig. 1. As indicated in Table 2 and Fig. 1, the maximum of the average of compressive strength value is 136.1 MPa for the RPC with glass powder of 20%. The glass powder in concrete has a role similar to silica fume in the binding process or pozzolanic reaction. Since the binding process takes second reaction ($Ca(OH)_2 + SiO_2 \rightarrow C\text{-}S\text{-}H_{II}$) that occurs in the cement paste, so it can be said with a percentage of 20% glass powder in the mix design has a SiO_2 content possibly similar to $Ca(OH)_2$ so that pozzolanic reaction that occurs is the maximum.

Table 2 and Fig. 2 show average of concrete split tensile strength test results and the maximum value is 17.8 MPa for the RPC with glass powder of 20%. For the average of concrete flexural strength test results, the maximum value is 23.2 MPa also for the RPC with glass powder of 20% (Table 2 and Fig. 3). The compressive strength test, split tensile strength test, and flexural test of specimen can be seen in Fig. 4, Fig. 5, and Fig. 6, respectively.

Table 2. Test results for concrete age of 14 days

No.	Glass powder content	Specimen $Ø \times h$ (mm)	Average compressiv strength (MPa)	Specimen $Ø \times h$ (mm)	Average split tensile strength (MPa)	Specimen $b \times h \times \ell$ (mm)	Average flexural strength (MPa)
		Cylinder		Cylinder		Beam	
1	10%	100x200	97.4	100x200	14.5	100x100x40	20.3
2	20%	100x200	136.1	100x200	17.8	100x100x40	23.2
3	30%	100x200	83.9	100x200	16.6	100x100x40	22.6

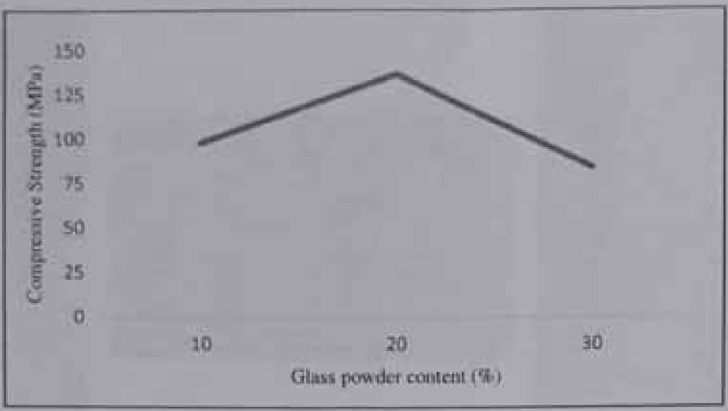

Fig. 1. Average of compressive strength of RPC with glass powder

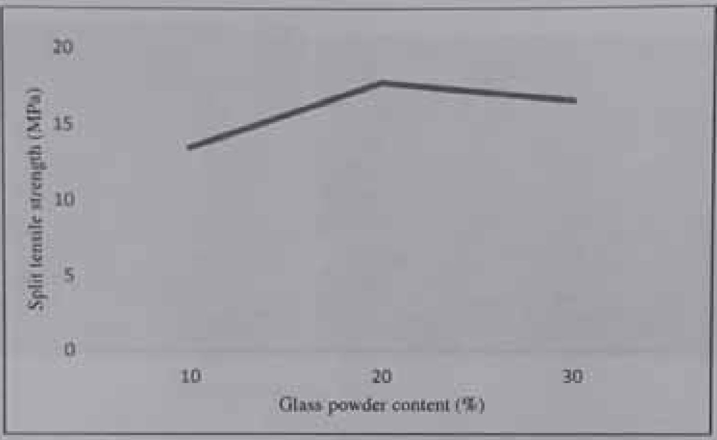

Fig. 2. Average of split tensile strength of RPC with glass powder

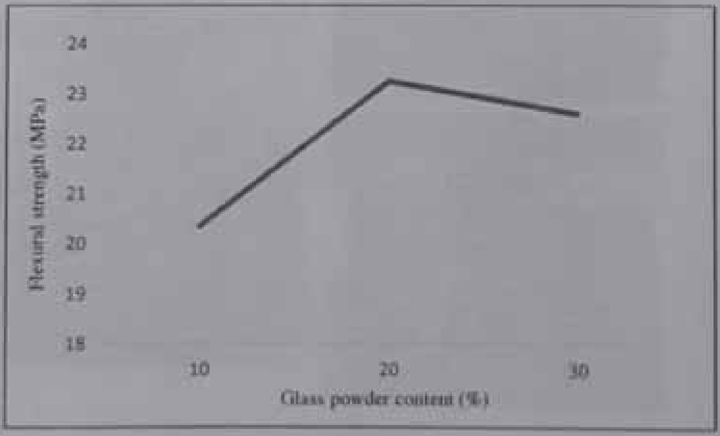

Fig. 3. Average of flexural strength of RPC with glass powder

Fig. 4. Compressive strength test.

Fig. 5. Split tensile strength test.

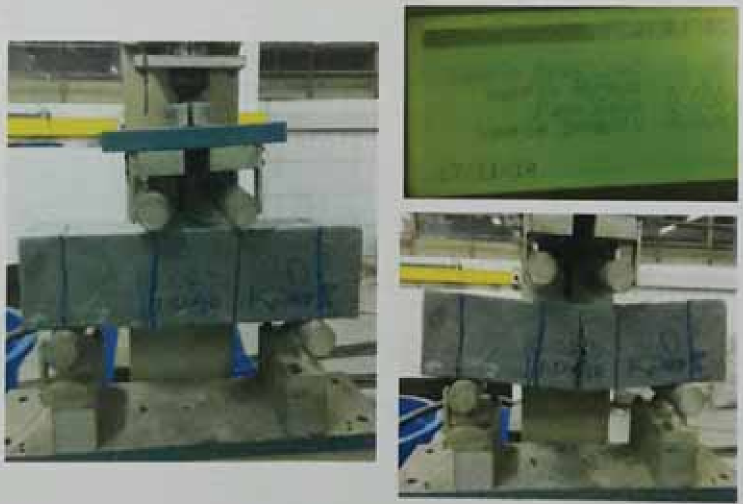

Fig. 6. Flexural strength test

5. Conclusion

After the experiments were carried out and comparing of RPC with glass powder of 10%, 20% and 30%, conclusion can be made as follows. The maximum of average of compressive strength value that can be achieved in this study is 136 MPa for the RPC with glass powder of 20%. The RPC with glass powder of 20% indicates also the maximum of average of split tensile strength value of 17.8 MPa and the average of flexural strength value of 23.2 MPa. The use of glass powder of 20% of the mass of cement in this study is quite good to substitute the quartz powder in the RPC in order to improve its mechanical behavior.

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CERTIFICATE

This is to certify that

Widodo Kushartomo

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