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Looking for Oil-free Building Materials Clay Pipes to Replace Polymer Pipes

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Abstract

After centuries of environmental pollution, many studies have illustrated the impact of oil and its products over the surrounding environment. Therefore, as a step toward sustainable neighbourhoods, it may an idea to search for alternative oil-free building materials. On the other hand, plastic is considered the main building material that derived from oil and used in a wide-range as (water system pipes, insulation material, plastic fibre for reinforcement concrete, etc.).
However, it is enough for these materials to be derived from oil to be polluting materials, but they are also strange materials to nature that they take thousands of years to decompose. Moreover, some materials like polystyrene it is not even accepted yet to be recycled because of the economic point of view.
All above has urged us to search for alternative eco-friendly materials, thus the natural materials that come from the earth like clay may be that one. So these papers are going to present the possibility of replacing plastic pipes with clay ones by test and analyze some specimens following the standards.
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*Keywords:*urban sustainable development; plastic building materials; alternative sustainable materials; clay pipes.

1. Introduction

Since the last century, global warming and environmental pollution have become the main issue of most sciences including urban planning. Moreover, there is a need to many studies for setting up suitable solutions in order to

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diminish this phenomenon. Therefore, taking a look of how the world has been developed in the last two centuries, may give us a comprehensive idea about the role of oil. There is no doubt, oil has been a significant factor on forming and developing urban space, where its products have entered in the many of the city's components.

Pollution is not just CO_2 emissions and people activities over the environment. Polymeric plastic materials, derived from oil, are one of the main factors of environmental pollution, not just because of their origin, but they are strange to nature and need thousands of years to degrade.

Till now, many research tried to find solutions for urban development problems by discovering new methods and materials, regardless if they are sustainable or not. In many cases, the main question remains: what is the impact of the new products regarding the environment? Therefore, looking back through history may give us good solutions for actual problems. Cities and buildings that stand since long time ago, facing all the climate and environmental factors are deserved to be studied to find right examples of sustainable urban elements and materials, in order to be used in actual modern cities. On the other hand, our world is running out of oil and thus its materials, and age without oil is not far to occur.

Obviously, the discovery of oil made a revolution in various fields, and building materials is one of them. As much as these new materials have made a big change over our cities, they equally had a terrible influence over the climate, because the environment and public health it was not taken into account. In the beginning, people were grateful to get rid of the natural materials and to replace them with new, modern ones. Thus, the present research aims to promote a sustainable natural material in order to replace non-ecological solutions, based on a look back to the pre-oil age. More specific, next the research is done on clay pipes, traditional solution for drainage and sewage since ancient times, replaced nowadays by cement and oil based products (e.g., concrete pipes, polymeric pipes).

The emergency of oil accompanied with wide-range materials that have started to be used in various fields. Building material was not so far to be influenced by this new revolutionary material, but more lots of building materials have made out of crude oil or its products. The influenced has not confined on materials that made directly out of oil such as Asphalt, or derived from it as polymers, some materials have made as composition between oil products mixed with other materials. In this paper we will focus just over polymer materials and especially plastic one.

The main materials that form plastic come from oil and natural gases, by range of synthetic and semi-synthetic organic condensation, or polymerization products, plastic can be converted into objects. This converted operation is a cracking process to obtain long chains of carbon and other elements that finally forming plastic [2]. Then it can be mixed with other chemicals to produce finished product like PVC soft, tough plastic, and many others. Bacteria, heat, light, color, and friction can also be added [3]. Plastic can be made from crude oil or manufactured from petroleum products that include liquid petroleum gases, natural gas liquids (NGL), and natural gas. The use of plastic in construction could be summarized as: High-density polyethylene (HDPE) plastic used in cabling, pipes, wood composites; Phenolics (PF) or (phenol formaldehydes) as Insulation for electronics; Polyamides (PA) as Nylon materials; Polypropylene (PP) plastic used in Pipes; Polystyrene (PS) plastic to produce foam products and insulation materials; Polyurethanes (PU) like foam products for furniture and coatings; Polyvinyl chloride (PVC) plastic to form pipes, shower curtains, flooring, windows [4].

2. The impact of plastic over environment.

Plastics in general act as pollutants; however it has been categorized based on size into micro, meso, or macro debris [5]. The existence of plastic products in the environment as strange materials led to adversely affects wildlife habitat and humans [6]. The comparative cheap price of plastic products leads to high levels of plastic used by a human which mean more wastes in the environment [7]. In addition, it is slow to degrade; plastic pollution can unfavourably affect lands, waterways and oceans through several ways like entanglement, direct ingestion of plastic waste, or through exposure to chemicals within plastics that cause interruptions in biological functions. There is no doubt that humans also affected as long as we cannot stay far from other species, these effects can be through the disruption of the thyroid hormone axis or sex hormone levels [8]. Even though plastic materials themselves are polluted, the chemical additive during plastic production has potentially harmful effects that could prove to be carcinogenic; some of these materials are used as phthalate plasticizers or as brominated flame retardants [9]. When Chlorinated plastic degrades in the environment can release harmful chemicals into the soil then to groundwater or surrounded water sources, may also into ecosystem [10]. Moreover decomposition of plastic results the release of toxic chemicals such as Bisphenol A [3]. The most dangerous phenomenon is when biodegradable plastics decompose releasing methane, which is a very powerful greenhouse gas that has significantly impacted to global warming [11].

3. Discussion

By considering the bad traces of plastic over environment, and knowing that oil is limit resources, a look back to the Roman civilization and their sanitation system that used in their outstanding baths to find out that complexes one had made out of clay. Clay is considered a good thermal mass; it is very good in keeping temperatures at a constant level. Buildings built of clay tend to be naturally cool in the summer heat and warm in cold weather. Clay act like a stone under heat or cold, where holds it and releases it over a period of time. So we choose clay as ecological sustainable materials [12] for constructions, in order to replace plastic pipes by clay one. However, vitrified clay pipes to be used in sewer system are already used since two or more decades, but not for water supply systems. Two manufacturing technologies are proposed:

- Treated clay pipes without burning, to be used in sewer system;
- Treated vitrified pipes to be used in the sanitation system.

3.1. Material selection

Sixteen samples of clay mixtures were manufactured to study their behavior (see Fig.1). The choice of the materials was done on parallelepiped specimens were in size of 40×40×160 mm. Treatments were made with thin films of sunflower oil

Fig.1. Clay specimens

The deciding factor for the quality of a clay product is connected to the quality of the soil being used. The other ingredients introduced into the specimens are various quantities of sand as gravel and straw as disperse reinforcement. One sample replaced sand with sawdust, which proved to be unsatisfactory. Some samples also included in the mass of clay (i.e., polyvinyl acetate) and bone glue. All materials are of local origin, as follows: clay from Valea Drăganului and Căpuş, sand from Poieni and straws from Bistriţa. Fig. 2 illustrates samples of the clay type and the sand used.

a  b c

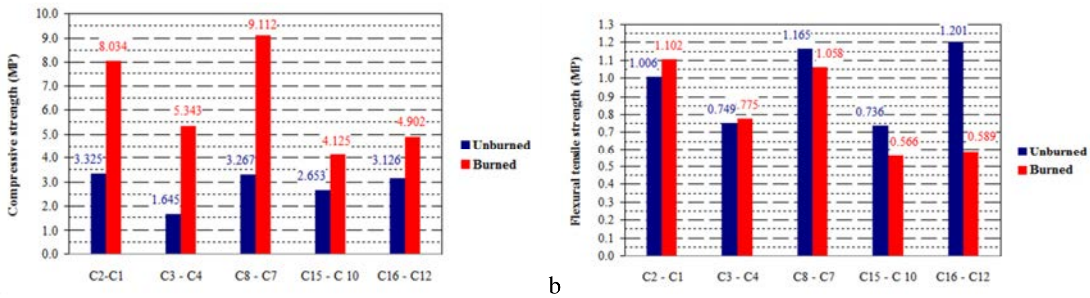
Fig.2. (a) the nature of clay; (b) crushed sieved clay “powdery clay; (c) type of sand used

To analyze the behavior of samples before and after burning, we burned gradually one sample of every mixture until 800 degree.

Then all the sixteen samples were tested under flexural tension and compression stress at the laboratory of INCERC Cluj-Napoca, to identify the best mixture in order to manufacture the pipes. The results are presented in Table.1

Table 1. Results of the preliminary tests on different mixtures

Sample	Composition	Weight g	Tensile strength MPA	Compressive strength MPA
C1	clay+aracet+sand 35 %+burnt	389.03	1.102	7.412-8.034
C2	clay+aracet+sand 35 %	413.16	1.006	3.189-3.325
C3	clay+aracet+sand 35 %+oil	453.5	0.749	1.631-1.645
C4	clay+aracet+sand 35 %+oil+burnt	400.2	0.775	4.929-5.343
C5	powder clay+aracet 20 %+straw+sand 35 %	330.87	0.873	2.050-2.464
C6	clay+bone glue+sawdust 10 %+burnt	323.23	0.827	4.164-4.728
C7	Powdery clay +Sand fine35%+ Burnt	385.97	1.058	9.112-9.434
C8	Powdery clay +Sand fine35%	415.52	1.165	3.267-3.382
C9	Powdery clay +Sand fine35%+glue 20%	398.98	0.962	2.853-3.264
C10	Clay +Sand 35%+ burnt	385.91	0.566	4.125-4.249
C11	Powdery clay + water extra 20%	360.52	0.724	1.917-2.081
C12	Clay+ burnt	401.89	0.589	4.547-4.902
C13	Powdery clay +Sand+ glue 40%	332.99	0.892	2.446-2.660
C14	Powdery clay +Sand+ Straw	399.58	1.045	2.378-2.423
C15	Clay	420.59	1.201	3.054-3.126
C16	Clay +Sand 35%	412.52	0.736	2.366-2.653



a b

Fig.3. (a) Influence of burning over the compressive strength; (b) Influence of burning over the flexural tensile strength.

Next, based on the results given in Table 1, Fig. 3a and 3b, for mixtures were selected (C3, C4, C7 and C8) to test them on pipe specimens and then to compare the results with the admissibility criteria given by EN 295. The pipe specimens were made manually, and it seems reasonable that if a hydraulic manufacturing technology would be used better results would be. Fig. 4. shows images taken during the calibration of the manufacturing technology. Firstly, the specimens cracked due to shrinkage and mold removal. Finally, the best technique found was the vertical extraction of the mold and constant temperature and humidity conditions (23 °C and RH=70 %). Fig.4 (a) presents the cracks that happened by using the mold and Fig.4 (a) presents the pipe specimens.

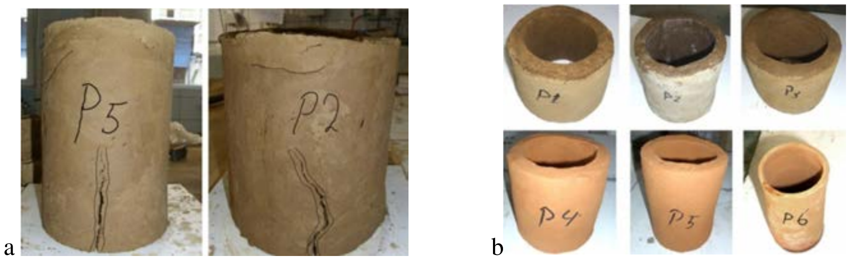


Fig.4. (a) the cracks that happened (b) Final pipes

Before we tested them we had worked to treat and fix all the cracks by adding the same mixture that samples have, then we work to treat 3 samples of them with natural materials and the other just by burning them until 900 degree. The treatment was by cladding the interior surface by layers of natural materials as illustrated in Table. 2

Table 2. Pipes sample characteristics.

Sample	Composition	Ex. Diameter	In. Diameter	height	Treatments layers
P1	Clay +Sand35% + without cracks	150 mm	115 mm	150 mm	2 layers of linseed oil
P2	Clay +Sand35% + Cracks	150 mm	115 mm	180 mm	2 layers of pork fat
P3	Powdery clay +Sand35%+ sunflower Oil	145 mm	127 mm	150 mm	2 layers of sunflower oil
P4	Powdery clay + Sand35%	150 mm	115 mm	150 mm	burnt
P5	Clay +Sand35% + Cracks	145 mm	127 mm	200 mm	burnt
P6 (a)	Powdery clay +Sand20%	65 mm	45 mm	10 mm	burnt
P6 (b)	Powdery clay +Sand20%	65 mm	45 mm	10 mm	burnt +Linseed oil

P1 and P2, P3 were preliminary tested by filling them by water and observe how much the treatment material prevent the leakage of water. P3 also was tested under water pressure. P4, P5, P6 were tested according to EN 295 [15] for drain and sewage system as flowing 1-Watertightness and crushing strength 2- air tightness of the pipes 3- water absorption 4- water pressure. Moreover, for P6, in both alternatives, even a higher pressure was considered, as for plastic pipes standard, to see if these pipes can replace the plastic ones.

4. Results

After applying the test we noticed that the samples that had cracks did not resisted when pressure reach 0.6 Bar. Moreover the treated samples like P2, P5 the water stared to appear on the exterior face after 2 hours around the cracks as clear appeared in Fig.5. (a), (b). For the sample P1 which did not have cracks, but was made out of large grains clay, it was so porous and water start to appear after one day on the exterior surface as shown down in Fig.5(c). With knowledge that the treated materials like Linseed and Pork fat had been given great results for waterproof by testing them by putting layers of these materials over clay dry samples and observe the decline of water according to time with taking into account the vapor factor as shown in Fig.6. All it has been said led us to observe that if samples have cracks it is not good at all and we cannot repair them, but for micro- cracks may be able to heal up when we burn the samples that the cells melt and fill it like the pour one. And that is why the vitrified pipes are less permeability. For the samples that do not have cracks like (P3, P4, and P6) there were not any problems with water leakage.

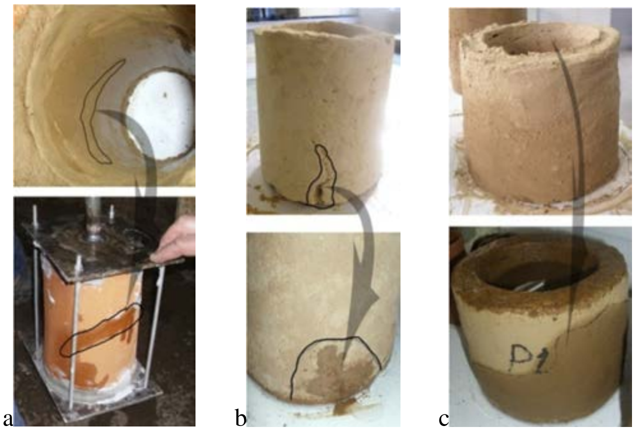


Fig.5. (a) Pipe P5; (b) Pipe2; (c) Pipe1

4.1. Airtightness of the pipes

According to EN 295-1 clause 5.18 and section 16 of EN 295-3, test setup consists in applying an air gauge pressure of 10 mbar for a period of 6 minutes. The acceptance criteria says that the gauge pressure must not drop below 7.5 mbar. Results are shown in.

Table 3. Airtightness

Sample	Test pressure [mbar]	Permissible Δp [mbar]	Test time [min]	Requirement fulfilled?
P3	10	2.5	6	Yes
P5	10	2.5	6	Yes
P6 (a)	10	2.5	6	Yes
P6 (b)	10	2.5	6	Yes

4.2. Water absorption of pipes

According IS 3495 (Part-2)-1992 RA 2011, the specimens were tested by drying in a ventilated oven at a temperature of 105 °C to 115°C, until they present substantially constant mass. After that specimens were subjected to cooling to the room temperature and obtain its weight. Immerse completely dried specimen in clean water at a temperature of 27+2°C for 24 hours. Take them out and gently dried with a towel and re-weighed. The average water absorption shall not be more than 20 %.

Table 4. Water absorption

Sample	Dry weight (g)	Wet weight (g)	water absorption (g)	water absorption %	Set values	Requirement fulfilled?
P3	2437	2512	75	3.077%	≤ 20%	Yes
P5	2998	3476	478	15.94%	≤ 20%	Yes
P6 (a)	2151.7	2537.3	385.6	17.92%	≤ 20%	Yes
P6 (b)	3128	3045.2	82.8	2.71%	≤ 20%	Yes

The specimens P3, P6 (b) fulfil requirements of water absorption according to set value DIN EN 295-1 which has to be ≤ 6%

4.3. Crush strength

For determining the crushing strength of vitrified clay pipes according to EN 295-1, clause 5.9, the pipes were preconditioned according to EN 295-3, clause 7.1.1, method a. That means immersing the pipes in a container filled with water at ambient temperature for a minimum duration of 66 hours. Then it was applied pressure force as shown down in Fig. 6. The results given in Table 5 show that all burned specimens (only these were tested, obviously the unburned specimen cannot fulfil) comply with requirements.

Fig.6. pipe P6 crushing test

The Table 5 illustrated the crushing strength for the three burnt pipes

Table 5. Crush strength

Sample	Preconditions [hours]	Force at break FN [KN/M]	Set values [KN/M]	Requirement fulfilled?
P5	≥ 66	60	≥ 40	Yes
P6 (a)	≥ 66	111	≥ 40	Yes
P6 (b)	≥ 66	105	≥ 40	Yes

As the results are shown all the specimens comply with Requirement.

4.4. Watertightness and water high pressure

The watertightness test has to follow the standard EN 295-1, clause 5.14 and EN 295-3, clause 12. The pipes have to be filled with water, and then apply a pressure of 0.5 bar for the duration of 1 hour precondition time. After another 15 minutes, the water adding should not exceed 0.7 l/m2 of the inner surface of the pipe, as shown in Fig. 7. Moreover, after the watertightness is tested and the maximum water pressure that every pipe can resist is known, a pressure is applied gradually until the point that water starts leaking out of the pipe. The corresponding pressure forces are compared with the admissible forces of the plastic pipes, and then, depending by the experimental values, their possible use is classified as shown in Table 6.

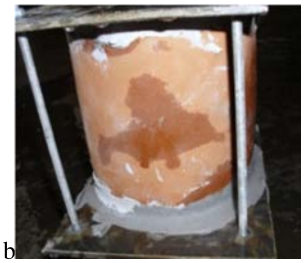
a  b  c 

Fig. 7. (a) Pipes under constant pressure of 0.5 Bar; (b) pipe P4 water leakage at 3.5 Bar; (c) pipe P3 under pressure of 1Bar.

Table 6. Watertightness and water maximum pressure

Sample	Visual inspection of leakage pipe surface at 0.5 bar	Water addition V/15 [L/M2]	Set values	Requirement fulfilled?	Maximum pressure [bar]	Field used
P3	No leakage	0.00	≤ 0.027	Yes	1	Drain and sewage
P5	No leakage	0.00	≤ 0.027	Yes	3.5	Sanitation system
P6 (a)	No leakage	0.004	≤ 0.01	Yes	8	Water supply system.
P6 (b)	No leakage	0.00	≤ 0.01	Yes	11	Water supply system.

5. Conclusion

The aim of this paper is to highlight the impact of plastic pollution over the environment, including human. Focusing on the concerning issue of plastic pipes, in order to be replaced by eco-friendly materials **'clay'**. At the same time, vitrified clay pipes have given us good results for using them in drain and sewage system; whereas treated vitrified clay pipes could be used in water supply system. Finally, unburned treated clay pipes *'with developing a bit its resistance'* may be a future step to be used in wide-range of water installation system. On the other hand, this paper considers a step for future work to find solutions for replacing the plastic pipes of electricity polystyrene insulation by eco-friendly materials.

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References

[1] Boyd R, Stern N, Ward B. What will global annual emissions of greenhouse gases be in 2030, and will they be consistent with avoiding global warming of more than 2°C?. ESRC Centre for Climate Change Economics and Policy Grantham Research Institute on Climate Change and the Environment; May 2015.
[2] Poonam A, (et al.). Interactive Environmental Education Book VIII. Pitambar Publishing. p. 86. ISBN 8120913736.
[3] ***. Chemical Society, American. Plastics In Oceans Decompose, Release Hazardous Chemicals, Surprising New Study Says. Science Daily. Retrieved 15; March 2015.
[4] Brydson JA. Plastic materials. October 1999. ISBN: 978-0-7506-4132-6
[5] Hammer J, Kraak MH, Parsons JR. Plastics in the marine environment: the dark side of a modern gift. Reviews of environmental contamination and toxicology; 2012; 220: 1–44. doi:10.1007/978-1-4614-3414-6_1.
[6] ***. Encyclopaedia Britannica. Plastic pollution. Retrieved 1; August 2013.
[7] Hester, Ronald E., Harrison, R. M. Marine Pollution and Human Health. Royal Society of Chemistry. 2011. pp. 84-85. ISBN 184973240X
[8] Mathieu-Denoncourt J, Wallace SJ, de Solla SR, Langlois VS. Plasticizer endocrine disruption: Highlighting developmental and reproductive effects in mammals and non-mammalian aquatic species. General and Comparative Endocrinology2014; 219:74-88.
[9] Barnes DKA, Galgani F, Thompson RC, Barlaz M. Accumulation and fragmentation of plastic debris in global environments.. Philosophical Transactions of the Royal Society B: Biological Sciences 2008; 364(1526): 1985–1998; doi:10.1098/rstb.2008.0205. PMC 2873009. PMID 19528051.
[10] Poonam A, (et al.). Interactive Environmental Education Book VIII. Pitambar Publishing. p. 86. ISBN 8120913736
[11] Gervet B. The use of crude oil in plastic making contributes to global warming. Renewable Energy Research Group Division of Architecture and Infrastructure Luleå University of Technology SE-97187 Luleå, Sweden; May 2007.
[12] Călătan G, Hegyi A, Mircea C. Ecological materials for construction. Proceedings of the 14th International Multidisciplinary Scientific GeoConference & EXPO – SGEM; Albena, Bulgaria, 17.06.2013-26.06.2014, Section: 26. Green Buildings Technologies and Materials; 2014. pp. 89- 96, ISSN 1314-2704.