LEGO-like sand reinforced polyester bricks are set to revolutionize the building world

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Construction is arguably the most conservative field of technology. But building with traditional concrete, bricks and mortar is slow and energy-intensive. And it requires skilled labor and materials which are not as readily available as most people think. These problems become especially poignant when dealing with sudden, large scale homelessness caused by a natural disaster. An innovative building technique using stackable, sand reinforced polyester bricks offers a solution to these problems.

When the successful, German businessman Gerhard Duss met his compatriot, the engineer Gunther Plötz, he did not jump at the chance to invest in his innovative ideas to use sand reinforced polyester. By mixing in a bit of polyester resin and hardener, Plötz could turn ordinary sand into a building material stronger than normal concrete. And the material allowed complicated shapes to be made extremely accurately. But Duss had turned his book wholesale business into a market leader, enabling early retirement. All he wanted now was to grow old in his new home in Florida with his wife and daughter, and work on his golf handicap.

Then, on January 12, 2010, just a few hundred miles away, an earthquake hit Haiti. Over 150,000 people were killed, 200,000 buildings were destroyed and nearly 2 million people were rendered homeless.

When faced with such a disaster, first order of business is survival: food, clean water and shelter. You can hold out without food for a few weeks and without water for a few days. But without shelter, exposure to the elements can kill you in one night, depending on the environment.

Dust saw the devastation and human suffering and wanted to help. That’s when he remembered Plötz’s work. So he came out of retirement and flew back to Germany.

Four months after the earthquake, they founded PolyCare (www.poly-care.co.uk and www.poly-care.de). A research team of less than a dozen people set out to develop a system that would enable disaster victims to quickly rebuild their own houses at low cost and with materials found onsite. The firm was set up in a former glass factory in Gehlberg (Germany), where in 1895 the first x-ray and cathode-ray tubes were made (https://www.dropbox.com/s/hg3qijz7ij991h/VTS_04_1.VOB?dl=0).

The new construction system had to meet German quality standards and it had to enable laymen to quickly build houses and take them apart again just as fast. This meant producing bricks in a mobile factory to high tolerances. That took over two years to develop: longer than initially expected.

The brick making factory

The heart of the system is a simple, highly mobile brick making machine (https://www.youtube.com/watch?v=Q_auHNsWr1o) (Fig. 1). It can be fit into one container, shipped all over the world and set up onsite (Fig. 2). One machine can produce enough bricks to build one house of about 100 m² every day.

A whole factory will cost 600,000 to a million euro. It fits into 4 containers and can produce enough bricks to build up to 1200 houses of 40 m² per year, all with local materials. Because the process is simple, the plant can be run by unskilled workers. The first one has already been sold to Tripoli, Libya.

“It is not hard to envisage several much larger plants producing 40, 50 or more houses per day to serve a complete region hit by a disaster,” says Ramon Gray. He is a partner in the PolyCare company, and the managing director of its UK branch. “In most cases the materials we are talking about are present relatively close to where you want to build. Desert sand is ubiquitous, but it is usually unsuitable as building sand. Or it is contaminated with other materials, which seriously degrades the ability to make traditional concrete. All that has no effect on us though. We can use all those materials.”

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In the Haiti disaster, governments around the world poured in billions of dollars and there are still thousands of people living in temporary accommodations. That is because with the traditional way of building, you cannot get enough manpower and material together. “You have to ship it all in,” Gray explains. “I understand that there were something like 200,000 foreign workers in Haiti last year. So you have a situation where there is a dire need to ship food in to feed the locals. But then you impose another 200,000 workers on the local population. This means the demand for food and the logistical demand goes up significantly. And you have to pay those foreign workers money which will then leave the country again. This is all self-defeating. It is much better to use local labor. Those people have lost their families, jobs, homes and everything. And now they are just forced to sit around and wait for the world food program to turn up to feed them. With our system, we can get them involved and motivated in building their own homes and communities, and at a standard the local market has never seen before.”

Polyester resin, which can bind even desert sand and other materials, is used instead of cement to create a polymer concrete 3–5 times stronger than ordinary concrete (Fig. 3). Desert sand makes up almost 90% of the material.

Sand, resin and hardener is mixed together into a lumpy porridge. This is then poured into a mold on a vibrating table which compresses the compound. The compound sets and the brick can be taken out of the mold in 20 min (Fig. 4). It is fully hardened and ready for use 24 hours later. “With ordinary concrete you would have to wait two to three weeks,” Gray says.

The bricks are large blocks that can simply be stacked (Fig. 5). They have LEGO-like pegs and are made to small tolerances. So they do not require cementing together and it does not take time
Laying the bricks
The first step in building a house with these bricks is making a level flat base of wet sand. This is usually done by making a 300 mm channel in the ground, filling it with sand and accurately levelling it. This is a very basic but highly effective way of building, originally used by the Egyptians to build their pyramids.

The actual walls start with pegged strips of polymer concrete. They are laid down onto the base and bolted together with small steel plates (Fig. 6). Just as with LEGO, there are special blocks for the wall-ends and tiles for making floors. The material is impervious to water, so there is no risk of damp coming up through the floor.

The actual bricks can then be stacked onto the polymer concrete strips (Fig. 7). This is as easy as stacking storage bins. It is actually easier than building with real LEGO: the pegs have a loose fit inside the bricks, so the bricks do not have to be pushed home. And no gluing or sticking together is required (Fig. 8).

After three layers of bricks have been put down, it is time to vertically feed in threaded rods and screw them into the base plates (Fig. 9). These are the bottom parts of tie-rods which will eventually run through the entire height of the walls, connecting the base to the roof. As the walls get higher, the tie-rods are extended with screw thread connectors. Gaps are left for windows and doors (Fig. 10).

The walls are capped off with top plates. Bolting up the tie-rods to those top plates and tightening them, turns the stack of loose bricks into a strong box-like structure. This structure does not need a foundation, just like a car with a unibody does not need a chassis frame. The stronger material as well as the stronger structural design makes these walls many times stronger and more resistant to bending forces than a brick or cement concrete wall.

This gives the added advantage that the polymer concrete house should be able to stand up to extremely heavy earthquakes. "When you get seismic activity, a building that is fixed into the ground will start cracking," Gray says. "But our buildings basically float on top of the ground. Probably in the middle of next year, we
will be starting an extensive project run by a German university to test exactly how earthquake resistant our buildings are.”

Bauhaus University has been cooperating with PolyCare doing all sorts of tests for over four years. The system is going through full building type approval in Germany. Most of it has already been certified.

For construction on extremely weak or unstable soil, a small foundation is of course used to prevent the building from sinking. This is comparable to the sand plates you use if your 4 x 4 gets stuck.

The PolyCare system can be used for building up to three or four stories high (Fig. 11). Although floor plates made of polymer concrete are used, wooden beams are still needed to hold up floors above ground level. But polymer concrete beams are being developed for that. They are probably going to feature fibers to increase flexural strength. As Gray explains, they are testing different reinforcing techniques: “In some cases we have used cardboard tubes. That works very well. And we are looking at plant based materials, like bamboo.”

For the roof, multiple, standard systems can be used. At the moment there is no polymer concrete solution for the roof yet. “That tends to work out relatively expensive,” says Gray.

The polymer concrete house is very affordable though. Where a normal house would cost around 600 euro per m² in a third world country, a PolyCare type house comes in at about 250 euro per m².

Rebuilding the economy

After the disaster has been taken care of, the factory can be shipped to the next disaster relief area. But it can also be left in the country to build more and bigger buildings.

For disaster relief, mainly small houses (20–30 m²) will be built (Fig. 12). But once the initial problem has been dealt with, usually
the need for more substantial buildings will arise. With the PolyCare system, those small houses can be taken down brick by brick and used to build larger buildings, just like you do with LEGO. So a refugee camp could be turned into for example a hospital or a university. “The building would then cost a fraction of the original price,” Gray says (Fig. 13).

The largest refugee complex in the world is a UNHCR site at the town of Dadaab in Kenya. There are 330,000, mainly Somali refugees living there in flimsy tents, distributed in five camps in a total area of about 50 km². “It has been there for over 25 years,” Gray says. “Frankly, the local government isn’t keen on having this huge camp in that area. So they do not want permanent housing to be built for it. But as we know the Kenyans are naturally hospitable people and want to help as much as they can. Our system would seem to offer the ideal solution. First of all, much better accommodation can be built really quickly. But then when the Somalis return to their home lands the houses can be taken down very simply and all that material used for the benefit of the local Kenyan people. They can use it to build schools, houses, hospitals, community centers, and etcetera. A school for 200 students for instance can be built within 2 weeks. In many ways this is a really good way of thanking and rewarding the host country for their hospitality.”

And if the factory is left at the disaster relief site, the local workers can use it to get their own fast build housing industry and economy going again, building bigger buildings and earning wages to afford them. After all, that was Henry Ford’s secret to success: an affordable product and high wages for unskilled workers, so they can buy the things they produce themselves (Fig. 14).

**Slum development**

There is a worldwide need for affordable housing. And not just for disaster relief. According to Dust, 1.2 billion people around the world are currently homeless or living in slums.

“We have huge numbers going into slums,” Gray adds: “Take Mumbai. I have been out there several times. The city is currently growing at a rate of two million people a year. Well in access of 1.9 million of them go into slums. That is not sustainable. On a worldwide basis homelessness represents a growing danger.”

In July 2016, Alejandro Aravena, the director of the Biennale Architettura, a biennial meeting in Venice of architects from across the world, talked about our current world as the Urban Age. By 2050, 70% of the world’s population is expected to live in cities, causing an ever increasing global need for housing. According to estimates by the US government, 1,000,000 houses a week have to be built at a cost of less than $10,000 each. Otherwise homelessness will pose a serious threat to global security. According to Alejandro, this goal can only be met if new building technologies are employed.

So solutions with sand reinforced polymers can play a very important part. Sand is one of the bottlenecks with traditional building technology. According to Ramon, China has already used up the same amount of sand in the last three years as the USA in the whole twentieth century. And in spite of the fact that Dubai, Abu Dhabi and Qatar are sitting basically in the middle of the desert, the buildings there have been built with sand imported from Australia, the Philippines and Europe.

**The financial and environmental cost of traditional concrete**

The problem is that sand suitable for building is a scarce commodity. Sand differs in color and granularity. Some grains are angular, others are round. Desert sand for example is usually not suitable for concrete manufacture. It is polished by the wind to a round form which will not durably fuse with cement to form stable concrete.

That makes logistics the biggest obstacle in trying to build houses for slums or disaster victims the traditional way: suitable building materials have to be brought into the area from a long way away. Transporting all those heavy materials across the world is not only expensive. It also wastes a lot of energy, causing carbon dioxide emissions. This comes on top of the emissions caused by the production of cement, which is the “glue” that holds
traditional concrete together. Cement is produced by heating clay-like materials in a kiln to 1400°C, grinding it up and combining it with gypsum. This is a very energy-intensive process. Cement production already accounts for around 5% of all global carbon dioxide emissions. This is expected to rise to around 4 billion tons in 2050.

So by replacing cement with polyester a lot of energy can be conserved, making it an eco-friendly alternative. Polymer concrete is not new, but it usually requires very pure materials and a rather high concentration of resin. PolyCare however have developed a method so that almost 90% of the material can be sand and gravel. And all types of sand can be used. According to Ramon the recipe of the mix is the crucial know how to make the polymer concrete work and they have already determined a good recipe for dozens of different types of sand: “We have invented a way of making polymer concrete using waste materials. We can use desert sand, but also fly ash from power stations, etcetera, with very similar results. The compressive strength is typically between 100 and 120 MPa, which is 3–5 times stronger than ordinary concrete. In bending strength, traditional concrete reaches about 6 MPa, our polymer concrete achieves over 30.” So they can turn worthless desert sand and waste materials into a viable construction material.

Polymer concrete is six times more resistant to wear than cement concrete. It is waterproof, impervious to grease, acid and frost and has a high resistance to chemicals, salt water and salty coastal air. The usable life is estimated to be well in excess of 100 years.

**Worldwide interest**

Gerhard Dust was chosen to be one of only 12 speakers at the 2016 Tedx Binnenhof “Ideas from Europe”, showcasing innovative solutions to social and environmental issues. Since then the genie is out of the bottle and the world is starting to check his system out.

There are negotiations with Senegal and Chad. Unicef and the UNHCR are interested. And for a Chinese company, PolyCare demonstrated that it is even possible to use the waste residue of a gold mine as the main filler for polymer concrete. The resulting material turned out to exceed Chinese building standards by a factor of 6–10. And because of the brick design, just 1 m³ of polymer concrete is needed to make 3–4 m³ of walling.

The process can provide super-fast construction of super strong buildings for homes, schools, medical centers, etcetera. And with a record 1.3 million migrants seeking asylum in the EU in 2015, the German government for example is now looking into using the process in Europe as well.

The accommodation problems caused by the refugee crisis highlight the larger problem of a deficit in housing construction worldwide, not just in the third world. There are housing deficits in Europe, Australia, the UK and the USA, just as in Africa, India and South America. And so the process is garnering interest from all markets beyond its original purpose of quick reconstruction and providing low cost housing for disaster relief, refugee camps and slum development. “The big problem with building across Europe and the UK is getting hold of traditional building materials and skilled labor,” Gray explains. “And so I will be forming a new company to build starter homes and mainstream, middle income housing in the UK. Using our polymer concrete bricks, we can build a house that looks like any other house in the UK or Europe within four weeks at a price 20 percent cheaper than in the traditional way of building. Because our buildings don’t impinge on any current resources, what we build will be additional to the current build rate. For the UK this could represent a very significant boost to the housing supply.”

The higher cost of the polymer concrete building materials is offset by the lower labor cost because the building process is faster and it does not require skilled bricklayers. Polymer concrete also enables function integration. With the PolyCare bricks, there is no need for double skinned walls or additional heat insulation. “Our blocks can already achieve an insulation value down to 0.21,” Gray says. “According to current building standards that has to be below 0.28 in the UK and 0.26 in Germany.”

**Glow in the dark**

PolyCare are also looking for other new ways to use their polymer concrete. For example they have patented “Lumino”, a process to incorporate photo luminescent particles into the matrix of the composite. Gerhard Dust came up with the idea for Lumino when he noticed the glowing floating lights of the night time forest jungle in the movie Avatar. “In Saudi Arabia and other Arabian countries, many cities are separated by long straight roads, which are very dark at night,” Gray explains. “It is quite common for crashes to occur on those roads at night because people come off the road. So the idea is to have two strips of our polymer concrete with Lumino in it down the center of the road. They do not require any electricity or maintenance and will shine brilliantly for about 8 hours.” (Figs. 15 and 16).

Building whole roads out of their polymer concrete does not seem to be an option, as Gray explains: “You cannot flow it in the same way as normal concrete because it sets incredibly quickly.”

Lumino is also used in a range of garden decorations (Figs. 17 and 18). “The material carries the European toys standard,” Gray explains.

**FIGURE 15**

Tiles with “Lumino” photo luminescent particles. They store solar energy during the day...
“We also produce Lumino toys with colored lights in it. They can be used as children’s night stand lights.”

It has taken six years since Gerhard Dust came out of retirement to start PolyCare. Five million euro has been invested up to now. Still, Dust is adamant he would do it all again. The only difference is that he would tell his wife it would take six years to make the project a success, instead of just three.