

An Improved Ballast and A Method of Assembling a Ballast

Field of Invention

[0001] The present invention relates to a ballast for use in keeping support structures upright and a method of assembling and disassembling the same. In particular, the present invention relates to a ballast for use in solar panel assemblies.

Background

[0002] The following discussion of the background is intended to facilitate an understanding of the present disclosure only. It should be appreciated that the discussion is not an acknowledgement or admission that any of the material referred to was published, known or is part of the common general knowledge of the person skilled in the art in any jurisdiction as of the priority date of the invention.

[0003] Solar energy is clean, generates no emissions and is the most promising renewable energy source for tropical countries with high average annual solar irradiation. High density urban environment has limited available land for the large-scale deployment of solar panels, thus there are increasing efforts to tap solar photovoltaic from the building's rooftop. In a land scarce country like Singapore, many people live in high-rise residential buildings (e.g., HDB flats), deployment of solar photovoltaics (PV) system on rooftops is highly important. Concrete ballasts are conventional solutions to installing solar panels on rooftops so that holes do not have to be drilled into the rooftop flooring (which could otherwise result in leakage). Concrete ballast is widely used in the construction sector because of its high density and low production cost. Precast or premanufactured concrete blocks are generally used in such ballasts as counterweight for the entire system.

[0004] However, the transportation process (from the manufacturer to rooftop mounting location) is very labour intensive. Upon arriving at the foot of the block, a crane may have to be deployed to hoist these concrete ballasts to the roof of the building. Roads and traffic may have to be diverted and blocked, causing great

inconvenience to residents. Moreover, the usage of cranes is subject to space constraints. In many precincts, it is not feasible to use a crane. For example, some buildings are too close to train tracks, no-fly zones or there is simply no feasible space for a crane to be mobilised. In such cases, workers would have to manually lift these concrete ballasts to the top of the building roof. The workers would have to use the passenger lifts to bring these concrete ballasts to the top of the building, thus inconveniencing residents. Each concrete ballast has a mass of 80 kg. It requires four men to move it and puts workers at risk of injuries. The toughest journeys are on the rooftops because lifting machinery cannot be deployed to the rooftop. This translates to higher labour cost. Workers are also prone to heat stress from working on rooftops. Furthermore, concrete has a huge environmental impact. Cement, a component of concrete, contributes the most carbon footprint. According to a recent article published by CNN, more than 4 billion tons of cement were produced in 2021, contributing 8% of global CO₂ emissions.

[0005] There is therefore a need for a device to alleviate one or more of the abovementioned problems.

Summary of Invention

[0006] The disclosure was conceptualized to provide an improved ballast in rooftop solar installations where there is no plausible area for the mobile crane to park and conduct material lifting to the rooftop, where the only way to lift the material up is through physical labour. It is also an object of the invention to reduce the carbon footprint in the usage of the improved ballast. The improved ballast may have a housing configured to receive fluid, polymer (such as a superabsorbent polymer) and minerals. Upon mixing of the fluid with the polymer, a stable gel may be formed. The polymer can absorb up to 1000 times its mass when mixed with fluid, thus allowing the improved ballast to achieve substantial mass. The minerals are used to increase the density of the hybrid ballast and provide weight while the polymer provides weight through the absorption of the fluid.

[0007] In an aspect of the invention, there is provided a device for providing support to a solar panel assembly. The device comprises a housing provided with a recess

and an opening. The housing is configured to receive a fluid, a polymer and one or more minerals through the opening. The mass ratio of the fluid to the polymer is between 125:1 and 160:1.

[0008] In some embodiments, the polymer is configured to absorb the fluid in the housing to form a stable gel.

[0009] In some embodiments, the polymer is a Superabsorbent Polymer (SAP).

[0010] In some embodiments, the SAP is sodium polyacrylate.

[0011] In some embodiments, the fluid is water.

[0012] In some embodiments, the mass ratio of the fluid to the polymer is 150:1.

[0013] In some embodiments, the housing is made of unplasticized polyvinyl chloride (uPVC).

[0014] In some embodiments, the one or more minerals are waste stones, rocks, gravel or any combination thereof.

[0015] In some embodiments, the housing has a mass and a volume and wherein for a predetermined mass of the housing, the volume of the housing is configured to decrease by increasing the mass of the minerals in the housing.

[0016] In some embodiments, the housing is configured to receive a sodium compound, such that the minerals and the liquefied polymer chemically react with the sodium compound to release the fluid that has been absorbed by the polymer.

[0017] In some embodiments, the housing is configured to receive water such that the liquefied polymer reacts with the water to release the fluid that has been absorbed by the polymer.

[0018] According to another aspect of the invention, there is provided a use of the device as described above for providing support to a solar panel assembly.

[0019] According to another aspect of the invention, there is a method of assembling the device as described above. The method comprises the of filling the housing with a predetermined amount of water; adding a superabsorbent polymer and one or minerals through the opening; allowing the water, the superabsorbent polymer and the one or more minerals to mix; and sealing the opening of the housing.

[0020] According to another aspect of the invention, there is a method of disassembling the device as described above, comprising the steps of unsealing the opening of the housing; flushing the liquefied polymer with water; pumping the fluid that has been released, out of the housing; and drying the polymer, minerals and the housing.

[0021] Other aspects and features of the present invention will become apparent to those of ordinary skill in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

Brief Description of the Drawings

[0021] The present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

[0022] FIG. 1 is an illustration of the elements to be added to a housing of the present disclosure;

[0023] FIG. 2 is a perspective view of the device in accordance with an embodiment of the invention which may be installed with a solar panel assembly;

[0024] FIG.3 is a perspective view of the device in accordance with another embodiment of the invention which may be installed with a solar panel assembly;

[0025] FIG. 4 is a close up perspective view of the device of FIG.2;

[0026] FIG. 5 is a flow diagram illustrating the steps of assembling the device in accordance with an embodiment; and

[0027] FIG. 6 is a flow diagram illustrating the steps of decommissioning the device in accordance with an embodiment.

Description of Embodiments

[0028] In order to illustrate the technical solution(s) to the embodiments of the present disclosure, embodiments of the present disclosure are described with reference to the drawings. It is appreciable that the drawings referred to are some examples or embodiments of the present disclosure. A person having ordinary skill in the art, without further creative efforts, may apply the present disclosure to other scenarios according to these drawings. For example, although the disclosure relates to a ballast for a solar panel assembly, a person having ordinary skill in the art would be able to apply the present disclosure to other uses which require base support, such as erecting heavy decorations, lighting and traffic or warning signs.

[0029] In various embodiments of the invention, there is disclosed a device for providing support to a solar panel assembly. The device comprises a housing provided with a recess and an opening. The housing is configured to receive a fluid, a polymer and one or more minerals through the opening. The mass ratio of the fluid to the polymer is between 125:1 and 160:1. Upon mixing the fluid with the polymer, a stable gel may be formed. The polymer can absorb up to 1000 times its mass when mixed with fluid, thus allowing the improved ballast to achieve substantial mass. The minerals are used to increase the density of the hybrid ballast and provide weight while the polymer provides weight through the absorption of the fluid. An improved ballast may therefore be provided. Using the improved ballasts, workers are only required to move the empty housing, minerals, and polymer to and on the rooftop. Fluid, which may be water, and which makes up the bulk of the weight, can be taken directly from a water tank on the rooftop. This will significantly reduce transportation labour from the work site to the rooftop, along with injury risk.

[0030] FIG. 1 is an illustration of the elements to be added to a housing of the present disclosure. The housing 20 has an opening and a recess. Fluid 12 and polymer 14 and minerals 16 may be added into the housing 20 via the opening. Fluid 12 may be any aqueous solution such as water or oil. Polymer 14 is preferably a superabsorbent polymer (SAP) that can absorb up to 1000 times its mass in water by osmosis. This enhances the density of the hybrid ballast whenever necessary to save on manpower cost for lifting heavier weights and vice versa. The polymer 14 is mixed with fluid 12 to create a solidified (or gel-like) compound that can be used to fill up the empty spaces between the minerals 16. By utilising the empty space with the stable gel, the density of the ballast is enhanced. Based on the material safety data sheet (MSDS), the polymer is stable and suitable compound to use under rooftop conditions where direct sun exposure is highly probable. The minerals are used to increase the density of the ballast and provide weight while the polymer provides weight through absorption of the fluid via osmosis.

[0031] The chemical properties of the polymer have been considered and concluded to be safe for rooftop solar applications. Firstly, the biodegradation of the polymer is slow and would not happen spontaneously if the conditions do not promote bacterial growth. Bioaccumulation is the process of accumulation of chemicals in or on an organism within the food chain. The polymer is unlikely to cause bioaccumulation due to its high molecular weight. It has low toxicity based on existing international controls and it is not listed under compounds that are endocrine disruptors or substances of concern.

[0032] Preferably, the SAP is sodium polyacrylate due to its safety, stability and superior water-absorbing characteristics. A small amount of sodium polyacrylate can absorb up to 1000 times its mass when mixed with water, allowing the ballast to achieve substantial mass. Adding sodium polyacrylate to water allows the mixture to be in a gel-like state, eliminating the risk of rapid loss of water in the event of a leak in the housing.

[0033] Sodium polyacrylate is commonly used in consumer products such as diapers, toys, and food additives. The inventors have experimentally determined that the

optimal mass ratio of water to sodium polyacrylate is 150:1. This ratio will maintain the mixture in a gel-like state. To test out sodium polyacrylate's suitability in the harsh environments on rooftops, the inventors set up a trial on a rooftop with the container containing the water-absorbed sodium polyacrylate. The trial was conducted over a period of 18 months and the content is observed to be stable.

[0034] While sodium polyacrylate is preferably used as the SAP, a person having ordinary skill in the art would be able to apply the present disclosure and use other suitable SAPs that are able to absorb and retain water. Such SAPs may be for example, Polyacrylamide-based SAPs, modified starch-based SAPs, cellulose-based SAPs, hydrogel-based SAPs or composite SAPs.

[0035] Fluid 12 may be any aqueous solution such as water or oil. If oil is selected as the fluid, then the corresponding SAPs utilized may be designed and used for oil related applications, for example, Polyolefin-based SAPs, polyurethane-based SAPs, modified cellulose-based SAPs, silicone-based SAPs or cross-linked SAPs.

[0036] Minerals 16 may be stones, rocks or gravel. In events such as construction demolition, renovation, etc, there are plenty of waste stones, rocks, or gravels that need to be discarded. These minerals may be recycled and reused for such purpose.

[0037] FIG. 2 is a perspective view of the device in accordance with an embodiment of the invention which may be installed with a solar panel assembly. The solar panel assembly 30 generally comprises a solar panel 32 and one or more mounting structures 34. The device for supporting the solar panel assembly comprises a housing 20 having an opening 22 (which may be sealed) and a recess (not shown). The housing 20 is configured to receive fluid 12, polymer 14 and minerals 16. As explained above, upon mixing the SAPs with water, the mixture will be solidified in a gel-like state. The housing 20 thus gains sufficient density to be used as a counterweight or support for the structures. As shown in FIG. 2, the solar panel 32 is mounted onto and supported by four mounting structures 34. A pair of housing 20 is attached to one another via one or more clamping mechanisms 24 (shown more clearly in FIG. 4). The mounting structure 34 may be removably attached to the pair of housing 20 via a mounting bracket 26 (see FIG. 4). In the illustration shown in FIG. 2, two pairs of

housing 20 are used to support the four mounting structures 34. The housing 20 is shown to be in a generally cylindrical shape. A skilled person would understand that the housing is not limited to a cylindrical shape but can take any form. The housing 20 is preferably formed of a uPVC pipe.

[0038] FIG.3 is a perspective view of the device in accordance with another embodiment of the invention which may be installed with a solar panel assembly. The solar panel 30 is mounted onto and supported by four mounting structures 34. The four mounting structures 34 are removably mounted to a housing 40 via one or more attachment means 44. The housing 40 comprises one or more openings 42 and is configured to receive water, minerals and SAPs.

[0039] FIG. 4 is a close up perspective view of the device of FIG.2. As shown in FIG. 4, the pair of housing 20 each has an opening 22 arranged to receive water, minerals and SAPs. The opening 22 may be sealed after the contents have been added into the housing 20. One or more clamping mechanisms 24 are positioned to fasten and mount both housings 20 together. A mounting bracket 26 is mounted on the clamping mechanism. The mounting bracket 26 is adapted to be attached to the mounting structure using fastening means which are known in the art. Depending on the load that the housing is required to bear, two or more housing 20 may be suitably attached to one another. Moreover, due to the cylindrical cross section of the housing in this illustration, at least two housings 20 should preferably be utilized when providing support.

[0040] The housing 20, 40 should preferably be made of a material that is able to withstand environmental conditions on the rooftop and be able to last at least 20 years. Typically, the housings will be under the secondary slabs and the solar panels and hence resistance to Ultraviolet radiation need not be a great concern. Other considerations such as fire hazard and toxicity must also be considered. The housing may be made of uPVC or HDPE since these materials are recyclable and can last through the lifetime of the solar panel.

[0041] Furthermore, in some rooftops, space may be an issue due to existing architecture on the rooftop. For instance, there may be water tanks, ducting, aircon

compressors etc which may limit the space a ballast can be installed. In the present invention, the housing can be designed and customized to fit into the limited space as explained below.

[0042] Assuming a worksite requires an 80kg hybrid ballast in a limited space of 0.055m^3 , a housing filled with water, sodium polyacrylate and 18kg of minerals (eg. recycled concrete) with a density of $2600\text{kg}/\text{m}^3$ will be able to achieve a volume of 0.055m^3 . In Table 1 below, an 8 inch uPVC pipe is used as the housing to contain the minerals, water and SAPs.

	Qty
Length of 8inch uPVC pipe	1.7m
Mass of sodium polyacrylate	320g
Mass of water	48 litres (equivalent to 48kg)
Mass of recycled minerals	18kg
Total mass of the hybrid ballast	80kg
Volume of hybrid ballast	0.055m^3

Table 1: Composition and specification of an 80kg hybrid ballast with 18kg of recycled concrete

[0043] From the example, the mass of minerals required can be calculated after knowing the volume and mass of the container, and mass of the gel-like mixture. The length of the uPVC can be obtained as follows.

$$V_{\text{container}} = A_{\text{container}} \times L_{\text{container}}$$

$$0.055 = 0.0324 \times L_{\text{container}}$$

$$L_{\text{container}} = \frac{0.055}{0.0324}$$

$$L_{\text{container}} = 1.70$$

where

$V_{\text{container}}$: Volume of container

$A_{\text{container}}$: Area of container

$L_{\text{container}}$: Length of container

The mass of the improved ballast can be calculated using equation (1).

$$M_{\text{ballast}} = 1000 \times \left(1 + \frac{1}{150}\right) \times (V_{\text{container}} - V_{\text{minerals}}) + M_{\text{minerals}} + M_{\text{container}} \quad (1)$$

where

Density of water is 1000kg/m³

M_{ballast}: Mass of ballast

V_{minerals}: Volume of minerals, where $V_{\text{minerals}} = \frac{M_{\text{minerals}}}{D_{\text{minerals}}}$

D_{minerals}: Density of minerals (e.g., recycled concrete with density of 2600kg/m³)

M_{minerals}: Mass of minerals

M_{container}: Mass of container = 8 x L_{container}

Simplifying the above equation gives us equation (2).

$$M_{\text{ballast}} = 1006.67 \times (0.0324 \times L_{\text{container}} - \frac{M_{\text{minerals}}}{2600}) + M_{\text{minerals}} + (8 \times L_{\text{container}})$$

$$M_{\text{ballast}} = 40.616 \times L_{\text{container}} + 0.612 \times M_{\text{minerals}} \quad (2)$$

Since L_{container} = 1.7m and the mass of the hybrid ballast is fixed at 80kg, the final mass of the minerals will be:

$$M_{\text{ballast}} = 40.616 \times 1.7 + 0.612 \times M_{\text{minerals}}$$

$$80 = 40.616 \times 1.7 + 0.612 \times M_{\text{minerals}}$$

$$M_{\text{minerals}} = 17.89 \text{ kg} \approx 18 \text{ kg}$$

[0044] Hence, by knowing the dimensions of the space available to install a ballast and applying the above calculations, the workers will be able to determine the amount of minerals that should be inserted.

[0045] FIG. 5 is a flow diagram illustrating the steps of assembling the device in accordance with an embodiment. The assembly process begins by transporting all the materials to the site. The SAPs may be pre-packed into sachets beforehand. The materials such as the empty housing 20, 40, SAPs 14 and minerals 16 are hoisted up to the rooftop. Water 12 may be obtained directly from the rooftop water tank, thus saving labor. The housing 20, 40 is then positioned at the correct position and then unsealed and filled with SAPs 14, minerals 16 and water 12. Once the mixture has stabilized in gel-like form, a worker may conduct a visual check before sealing up the housing 20, 40. The housing 20 may be attached to one another with the one or more clamping mechanisms 24. The mounting structures 34 are then mounted onto the

housing 20 via mounting bracket 26. Finally, the solar panel 32 is supported and installed onto the mounting structures 34.

[0046] Solar panels have a life span of approximately 25 years. International building protocols are constantly updated to match sustainability standards. BCA updated Singapore's demolition protocol to maximise the recovery of waste materials for beneficial reuse or recycling. The decommissioning of the improved ballasts fulfils these requirements unlike concrete ballasts. The decommissioning procedure is illustrated in FIG. 6.

[0047] FIG. 6 is a flow diagram illustrating the steps of decommissioning the device in accordance with an embodiment. The housing 20, 40 is unsealed and the gel-like SAP is flushed out with water. By flushing the gel-like mixture with water, the mixture will be liquified. A hose may be utilized to remove the water from the roof top to the ground level. The diluted mixture is then allowed to dry under the sun. The evaporation process will significantly reduce the water content and allows the SAP to be reused for a next project. Once the housing (eg. uPVC pipes) reaches the end of its life, it can be recycled.

[0048] Manpower requirements are also a crucial aspect when evaluating sustainability metrics. Pivoting from the improved ballast from the concrete ballast solution presents significant manhour reduction. Table 2 below shows the manhour breakdown and comparison between the two methods. The total labour cost saved is approximately S\$2,280 per 50 ballasts.

Task	No. of Workers	Total Lead Time, hour (Conventional)	Total lead time, hour (Hybrid)	Total Manhours (Conventional)	Total Manhours (Hybrid)	Remarks (Manhours = No. of Workers x Lead Time)
Loading into transport	2	0.5	0.3	1	0.6	

Unloading from transport to hoisting site	2	0.5	0.3	1	0.6	
Moving of ballasts during hoisting	4	1	0.2	4	0.8	10 concrete ballasts per lift. Spreading of load once at the rooftop.
Load distribution on rooftop	4	3	0	12	0	
Transport to position	4	4	1	16	4	
Addition of water and SAP into Hybrid ballast	1	0	6	0	6	Assume single water point at rooftop and flow rate of 10 liter/min.
Fixing the structure to ballast	2	16	8	32	16	
Grand Total		25	15.8	66	28	Manhours saved: 38 hours

Table 2: Manhour and lead time comparison between concrete and hybrid ballast

[0049] Concrete is made by mixing water, sand, gravel and cement. Of all the components, cement is the most carbon-intensive to produce. Table 3 shows the carbon emission for each component.

Cement [5]	PVC [6]	Water [7]	Sodium Polyacrylate [8]
0.9 kg CO ₂ e	0.345 kg CO ₂ e	0.0013 kg CO ₂ e	3.79 kg CO ₂ e

Table 3: CO₂ emissions per kg of production

[0050] A typical concrete ballast contains 16% cement. Hence, an 80kg concrete ballast will require 12.8kg of cement and 5.6L of water. Table 4 below summarises the carbon footprint from the production of concrete ballast and hybrid ballast. As water is main component contributing to the weight of the hybrid ballast, the carbon footprint that an 80kg concrete ballast generates is 1.54 times higher than an 80kg hybrid ballast.

Concrete Ballast (80kg)			Hybrid Ballast (80kg)		
Component	QTY	Carbon Footprint (kg CO ₂ e)	Component	QTY	Carbon Footprint (kg CO ₂ e)
Cement	12.8kg	11.52	uPVC pipes and components	16.9kg	5.831
Water	5.6L	0.007	Water	64L	0.083
			Sodium Polyacrylate (SAP)	0.420kg	1.59

Total carbon footprint of concrete ballast		11.527	Total carbon footprint of hybrid ballast		7.504
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Table 4: Carbon footprint comparison between a hybrid ballast and concrete ballast

[0051] Solar panel systems have a lifespan of 25 years. After which, the improved ballast can be redeployed to a second site. The extensive lifespan of uPVC pipes, coupled with high recyclability of sodium polyacrylate justifies for solar PV redeployment. Conversely, concrete ballasts have a lower redeployment rate as it is difficult to transport and has higher risk to damages and cracks.

[0052] With the aforementioned disclosure, it will be apparent that the present invention provides an improved ballast for supporting solar panel assemblies. The improved ballast allows higher productivity in that speed of deployment and redeployment is increased. The usage of the improved ballast of the present disclosure also achieves a lower carbon footprint and great possibility for redeployment. Safety concerns are also minimized since the improved ballast involves lifting a light-weight ballast. Also, the improved ballast ensures access to affordable, reliable and sustainable energy.

[0053] It will be apparent to those skilled in the art that various modifications, variations, substitutions, and equivalents exist for features of the system which do not materially depart from the scope of the invention.

[0054] It should be further appreciated by the person skilled in the art that variations and combinations of features described above, not being alternatives or substitutes, may be combined to form yet further embodiments falling within the intended scope of the invention.

Claims

1. A device for providing support to a solar panel assembly, comprising:
a housing provided with a recess and an opening, the housing configured to receive a fluid, a polymer and one or more minerals through the opening, wherein the mass ratio of the fluid to the polymer is between 125:1 and 160:1.
2. The device of claim 1, wherein the polymer is configured to absorb the fluid in the housing to form a stable gel.
3. The device of claim 2, wherein the polymer is a Superabsorbent Polymer (SAP).
4. The device of claim 3, wherein the SAP is sodium polyacrylate.
5. The device of any of the preceding claims, wherein the fluid is water.
6. The device of any of the preceding claims, wherein the mass ratio of the fluid to the polymer is 150:1.
7. The device of any of the preceding claims, wherein the housing is made of unplasticized Polyvinyl Chloride (uPVC).
8. The device of any of the preceding claims, wherein the one or more minerals are waste stones, rocks, gravel or any combination thereof.
9. The device of any of the preceding claims, wherein the housing has a mass and a volume and wherein for a predetermined mass of the housing, the volume of the housing is configured to decrease by increasing the mass of the minerals in the housing.
10. The device of any one of claims 2 to 9, wherein the housing is configured to receive a sodium compound, such that the minerals and the liquefied polymer chemically react with the sodium compound to release the fluid that has been absorbed by the polymer.

11. The device of any one of claims 2 to 9, wherein the housing is configured to receive water such that the liquefied polymer reacts with the water to release the fluid that has been absorbed by the polymer.
12. Use of a device according to any of the preceding claims for providing support to a solar panel assembly.
13. A method of assembling the device of claims 1 to 11, comprising the steps of:
 - filling the housing with a predetermined amount of water;
 - adding a superabsorbent polymer and one or minerals through the opening;
 - allowing the water, the superabsorbent polymer and the one or more minerals to mix; and
 - sealing the opening of the housing.
14. A method of disassembling the device of claims 1 to 11, comprising the steps of:
 - unsealing the opening of the housing;
 - flushing the liquefied polymer with water;
 - pumping the fluid that has been released, out of the housing; and
 - drying the polymer, minerals and the housing.