Glass beads instead of filter gravel used as borehole filter material

Filling compound To date, sand and gravel, in accordance with DIN 4924, have been used exclusively as filling compound between the borehole wall and the construction pipe, for the support of bored holes for water extraction. This natural material is getting scarcer; the supplied quality is often not sufficient for the mineral requirements for the construction of wells. In its search for alternatives, the company, Ochs Bohr GmbH, is convinced it has found the ideal filling- and support material for modern well construction: beads of glass. Therefore, since September 2007, predominantly glass beads are used in place of sand and gravel in holes for water extraction.

For the extraction of groundwater or for the measurement of the ground water table it is necessary to sink vertical bore holes in the aquiclude. Depending on the demands, standardised construction pipes made of steel or PVC are hung in the borehole. Then the ring space between the filter pipe and the borehole wall is filled with standard sand or gravel. The gravel/sand determined, in accordance with the DVGW data sheet W 113, sometimes also incorrectly described as 'filter gravel/sand', is intended to ensure the following:

- optimal hydraulic expansion of the filter inflow surface to the borehole wall
- Highest possible effectie pore space through exact equal particle size and spherical shape
- allowing the finest grain share pass during development or desanding
- formation of a support grain between the well pipe and the borehole wall
- but by no means filtering of undersized particles or turbidities

The sand or gravel built into a well is supposed to support, not filter. Filtering is reserved for the sands and gravels, in accordance with DIN EN 12904 (formerly DIN 19623).

Sands and gravel, in accordance with DIN 4924, are unbroken natural quartz sand and gravel, without crimped or broken minerals. The requirements, in detail, are:

- continuous development of the grain size distribution within the individual grain groups
- at least 96 % SiO_2 mass share
- a maximum of 1 % mass share of clarified components
- no organic materials
- no release of taste, odour, colour or materials which are hazardous to the health in hygienically questionable amounts into the ground water
- in the grain groups of up to 5.6 mm, the individual grains should at least have a rounded edge
- maximum permissible mass shares of undersized particles – 12 %, of oversized particles – 15 %

Although the last two named points strongly limit the suitability for well construction, the well constructor must cope with the product supplied in accordance with DIN 4924.

Often the well builder, as supplier of the well gravel, has difficulties and discussions with customers since the form of the individual gravel grains that are planned for the well construction cannot be described as spherical at all. It is apparent that the supplied gravel sometimes looks as though it has been broken, although this should not be the case according to DIN 4924.

In practice, the gravel is delivered in big packs or sacks. The undersized particles are usually in the lower area of the packaging, and thus cannot be recognised before the installation. If, for example, somewhat longer breaks are taken when pouring the gravel, watertight sediment layers of undersized particles can form within the gravel filling.

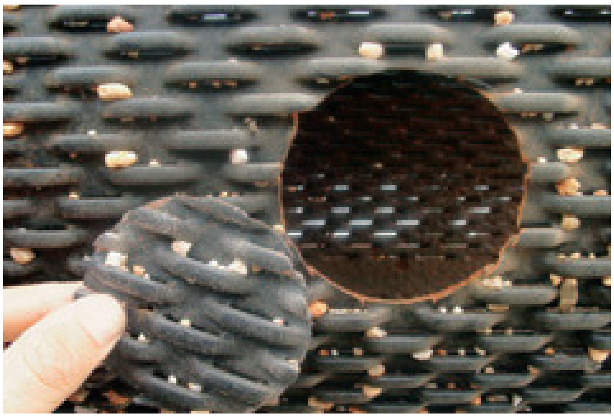
The undersized particle amount developed in the course of installing the gravel is substantial in the ring space between the well pipe and the borehole wall. If one assumes commonly used measures, installation DN 400 / boring diameter 700 mm or installation DN 300 / boring diameter 600 mm, then for each running metre of well filling approx. 0.25 m³ of sand or gravel is necessary. With a 10 % undersized particle share, there are 25 ltr. (or 2.5 construction buckets), of this for each metre of well depth. This must be laboriously and cost intensively rinsed from the ring space in the course of the well construction. One must assume that filter slit openings are closed during the construction with the gravel / undersized particles conglomerate. Therefore, the undersized particles and the (not even nearly round) shape of sand or gravel grains are unfavourable for the well construction, because there are no sufficiently large porous spaces between the individual grains.

When renovating wells, undersized particle shares of the gravel filling were often found to be steadily wedged in the slit bridges of the filter pipes, almost completely closing them. Furthermore, an increased sanding of the gravel material was observed after regeneration work, predominantly with the use of pressure wave impulse procedures.

Especially in the course of intensive well regeneration work it becomes obvious, that the well gravel cannot always resist the mechanical burden, since broken and rounded off material is on the market, which does not correspond with DIN 4924. The filter slot colmation caused by this, which cannot be avoided by the regenerator, can cause the water table to sink lower than before the completion of the work.

The often substantial amount of dust particles in the well gravel and sand is also a problem, since silicate dust can cause serious lung damage. Corresponding safety precautions, such as wearing dust masks, are to be adhered to. In the well boring, this fine mud can indeed permanently close off smaller porous spaces. In the course of the filling of the ring space, the available water must be drained. Compared with the available aquifer, a strong over-pressure in the borehole is established and, through the pressure equalisation, the undersized particles are pressed in the waterways. Therefore, even with a very deep water table of less than 50 m, it can occur that the water level rises and the well temporarily floods. In such cases, the fine particles in the gravel are pressed into the borehole wall with an over-pressure of 5 bar, which corresponds with 50 to/ m². Therefore, after the construction of the well, it was often no longer possible to pump out the same water amounts as from the open borehole. In such cases, the well builder can’t be blamed since he, according to the generally recognised rules, used quartz gravel in accordance with DIN 4924. Rinsing water paths which have once been sealed off is troublesome and not always successful. In short, the natural materials sand or gravel have the following disadvantages:

- no spherical shape
- high undersized and oversized particle shares
- high share of dust or clarified materials
- It is no londger necessary to claen the water well after the filling
- no satisfactory rigidity
- cost intensive development work necessary
- colmation of the filter slits is possible



Glass beads

As an alternative support material, the use of glass beds is recommended. These have the following advantages:

- highest possible effective porous space through exactly the same grain sizes and ideal bead form
- slot width of the filter pipes can be optimally adjusted since a single media filter bed is possible
- no pumping clean or cleaning of the glass material is necessary;
- no disinfection before filling necessary
- lowest possible and smooth surfaces, thus delay of iron and manganese sedimentation
- optimal regeneration through large porous spaces;
- no belated settling
- thanks to a low material friction the filling of the glass material is possible also in narrow ring spaces without the danger of bridging
- greater material rigidity of the glass beads in comparison to quartz gravel
- with camera examinations within winding wire filter pipes the sedimentation of iron ochre or foreign materials and bodies in the ring space can be clearly recognised

Material characteristics of the glass beads

The main chemical components of the soda-lime glass beads are:

SiO_2:	MA. %	72.5
Na_2O:	MA %	13.0
CaO:	MA %	9.06
MgO:	MA %	4.22
Other:	MA %	1.22

The glass beads are produced with differing processes, depending on the diameter. None of the glass components can be eluted, meaning they cannot be released. For safety reasons corresponding elution tests were carried out in the AIR laboratory in Nuremberg before the first filling of the material. The result was, as expected. Absolutely no foreign materials can be passed on to the water by the glass.

Firmness

The firmness of the glass beads depends on their diameter. In principle, the same rule of thumb applies as with sand or gravel. The larger the diameter of the beads, the higher the compressive strength.

In the laboratory of the glass bead manufacturer Sigmund Lindner GmbH, compressive strength experiments were carried out on glass beads, and also in comparison, to quartz gravel grains. The pressure devices used for this, exercised an axial pressure on the glass beads or the gravel grains. Quartz gravel grains, with a grain size of 5.6 mm to 8.0 mm from two different suppliers, were tested and also in comparison to this, glass beads with the diameters 2.5 mm, 9.0 mm and 12.0 mm. From all categories five individual specimens were examined. This resulted in the values shown in **Table 1** (kN). The breakage conduct of the gravel grains was a stronger and stronger 'crumbling' in the course of the pressure experiment, whereas the glass beads suddenly burst into the smallest pieces after reaching the ultimate strength.

Chemical resistance

Examinations of glass exist, in accordance with DIN 12116 Resistance to attack by a boiling aqueous solution of hydrochloric acid, as well as DIN ISO 695 Resistance to attack by a boiling aqueous solution of mixed alkali. In doing so, the glass samples were added to boiling acid or alkalis. The examination results showed an acid resistance class of S2 (slightly dissolvable in acid) and A2 (moderate damage through alkalis). When exposed to the conditions in the wells, there is absolutely no danger to the material, even with temporary use of acids (regeneration) or alkalis (disinfection).

Size and weight

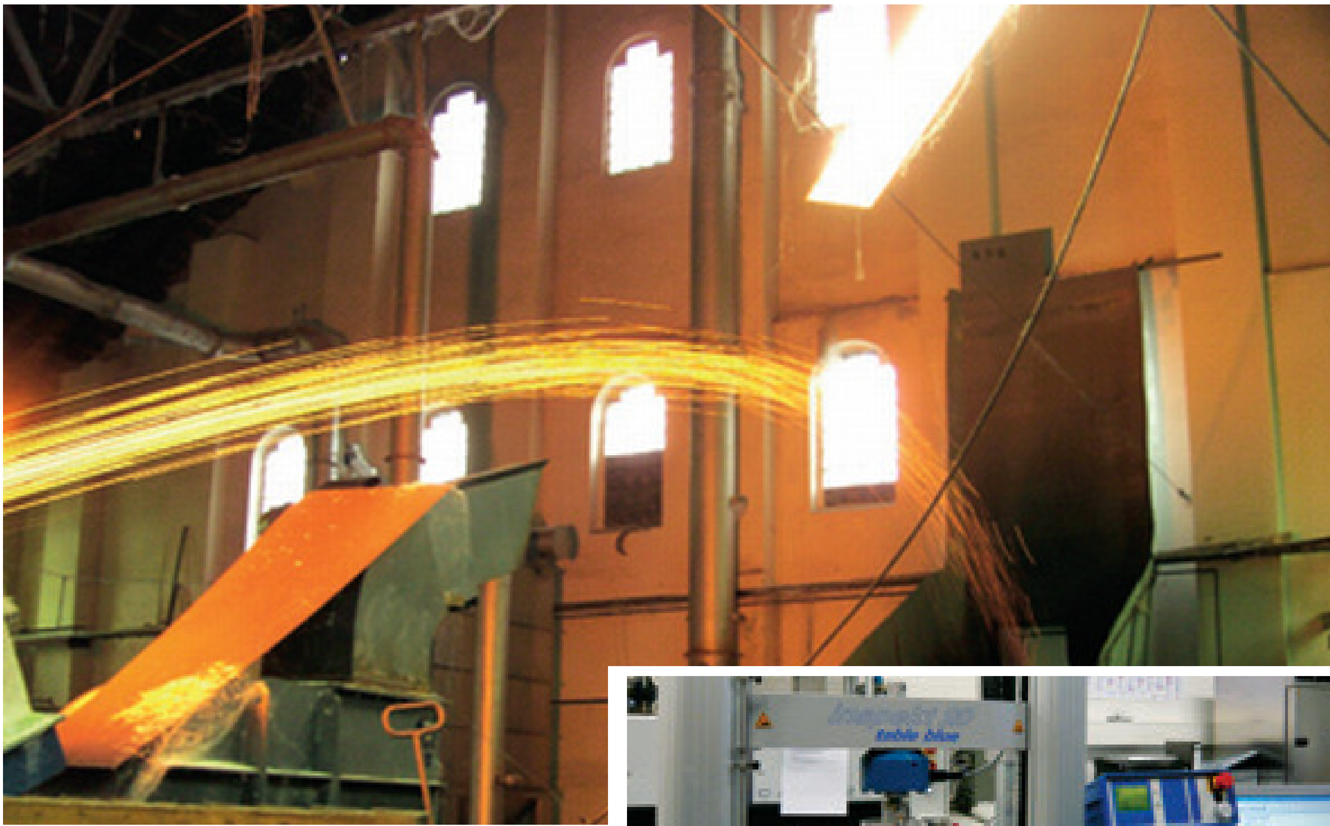
The glass beads can be supplied in sizes from approx. 0.25 mm to 18 mm. A bead with a diameter of 12 mm has a weight of approx. 2.26 gr. About. 442 beads are necessary for 1 kg. Based on the bulk weight, the surfaces and free porous spaces of the glass bead filling can be calculated.

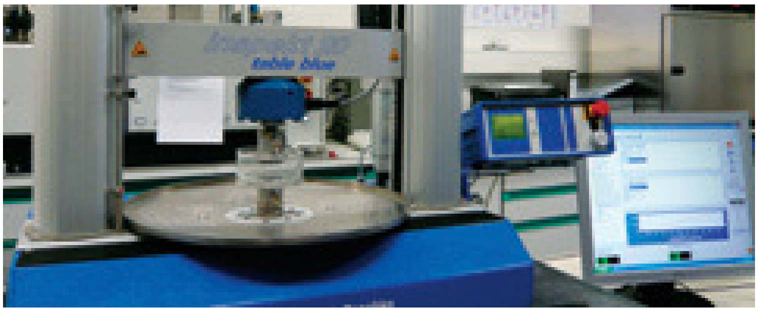
Efficiency

The acquisition cost of the glass beads depends on the size. Smaller diameters of up to 4.5 mm are somewhat cheaper than large diameters of up to 16 millimetres.

Material	Average	Min. value	Max. value
Gravel 1, 5, 6 – 8.0 mm	0.738	0.439	1.182
Gravel 2, 5, 6 – 8.0 mm	0.87	0.384	1.128
Glass bead D = 2.5 mm	1.141	0.885	1.334
Glass bead D = 9 mm	11.105	8.051	14.573
Glass bead D = 12 mm	14.201	11.616	15.951

Table 1 Firmness values glass beads / quartz gravel (kN)





The price for delivery, transport and filling with chutes is between 900 € and 1,300 € for 1m³. The prices for quartz gravel / sand are normally between 150 € and 200 € for 1m³. Therefore, when using glass beads, one must calculate additional costs of up to 1,100 € for each 1m³ of supporting material. If one takes, for example, a flat well with a depth of 20 m, construction DN 400 and a boring diameter of 800 mm, a total of approx. 7.5 m³ of supporting material is needed. The use of glass beads with a smaller size, means an additional cost of approx. 5,625 € (6,750 € for the glass minus the gravel costs of 1,125 €).

The savings effect with desanding work is approx. 1,500 €, according to the previous practical experience with a well of this size. The additional costs amount to 4,125 €. With overall construction costs of approx. 45,000 € for the flat well, which corresponds with approx. 9 % of the construction sum. The use of the glass material in this example is economical if in the course of the operating time of the well, only a single well regeneration with all associated additional work can be avoided.

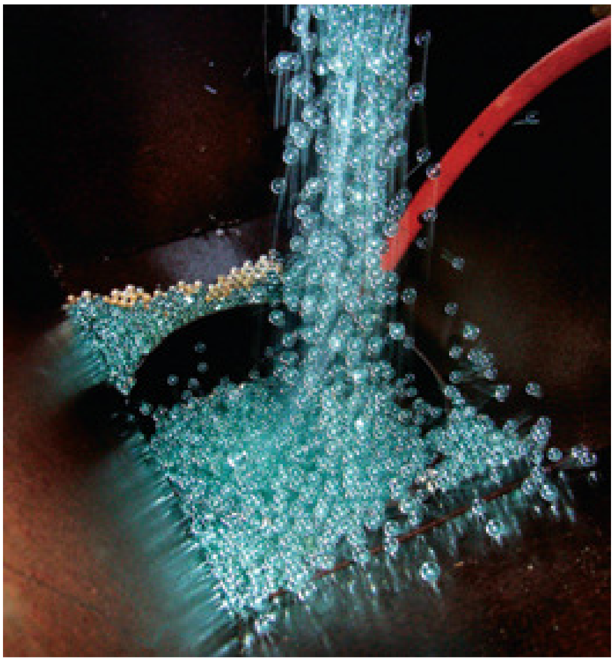
With a deep well, with a depth of 100 m, a construction DN 400 and a boring diameter of 700 mm, approx. 26 m³ of supporting gravel is needed. The additional costs with this well are approx. 23,800 € (29,000 € for the glass minus the gravel costs of 5,200 €). The savings effect of the clarification or desanding pumps with wells of this size are approx. 8,000 €. The additional costs are then approx. 15,800 €. A total building cost of the well of 250,000 €, this corresponds with approx. 6 % of the construction sum. Also, in this case, the additional costs are compensated through the omission of well regeneration work in a financial scope of 15,800 €.

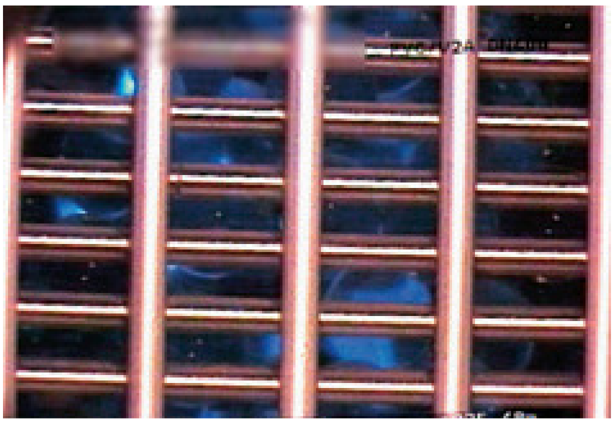
With this calculation, the increasing costs for regeneration work are not taken into consideration. It can be the case that a regeneration, which today costs 10,000 € will be twice as expensive in ten years through increased salary and energy costs. The current situation of salary and price increases is a strong indicator for this.

Efficiency can still be increased, if the glass beads are only built into the areas of the water column in the well. In dry areas, or within blockage pipes, common gravel can be used as an alternative.

Result

The approx. 10 % larger porous space of the glass beads alone, in comparison to gravel, would by no means justify the substantial additional costs. Wells which have absolutely no sedimentation of iron ochre, for purely economical reasons, a filling with glass beads is not recommended. With all wells which require a certain regeneration expense, there is already feasibility with the omission of a single regeneration through the operating duration of the well (taking into consideration the inflation of one half of a regeneration). The average age of wells built today with stainless steel construction pipes amounts to approx. 70 years. The regeneration interval is between 5-10 years, which means that for each well between 7 and 14 regenerations can be expected in the course of its operating time.





Literature

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DIN 12116, Issue March 2001, Beuth GmbH, Berlin
DIN ISO 695, Issue February 1994, Beuth GmbH, Berlin,
DVGW fact sheet W 113, Bestimmung des Schüttkorndurchmessers und hydrogeologischer Parameter aus der Korngrößenverteilung für den Bau von Brunnen, Issue March 2001, wvgw mbH, Bonn.

All illustrations: Ochs Bohr GmbH

Construction examples and experiences

Since September 2007 to the writing of this manuscript, Ochs Bohr GmbH has provided three deep wells with a construction depth of up to 130 m in solid rock, and a flat well with a boring depth of 16 m in loose stone with glass beads. The glass beads were delivered in big bags on pallets. To date, no faulty glass bead has been found.

The first use of glass beads with a diameter of 9.0 mm occurred in a solid rock well in the community Roßtal, in the county of Fürth. In the following solid rock wells, beads with a diameter of 12.0 mm were used. The beads were flushed in through a woven hose DN 100 (A-hose). This was always lowered to the still water level and removed again in the course of the filling. Partially up to 50 m of hose were necessary. For each big bag with approx. 1 to of weight, an average of 12 min filling time was necessary. For 10 to of glass material, the filling time was approx. 2 hours. A disinfection of the material before the filling was not necessary.

The desanding and development times of the wells have been halved in comparison to gravel wells of a similar size.

With a loose stone well, the determination of the required grain size, in accordance with DVGW rules and standards, resulted in 2.5 mm. A bead size of 2.5 mm to 2.9 mm and a slot width of the winding wire filter pipes of 2.0 mm were selected. Also, in this case, the desanding process could be shortened. There were absolutely no problems with the sanding or colmation of the glass beads and filter slots. What was noticeable, however, was the low coat friction of the glass beads in comparison to the gravel when pulling the boring pipes during the filling process. The danger of the well pipes being pulled up when removing the accessory piping was strongly minimised. The final camera inspection within the winding wire filter pipes, with up to 3.0 mm slot width, showed quite new views. With radial views, the blue, glimmering water level sensor can be recognised within the glass beads filling. Foreign bodies or sedimentation of iron ochre can be easily recognised with a good camera technique.

Conclusion

Glass beads are the ideal connection between filter pipes and bored earth. The experiences, made cause us to expect that this innovative new material for well construction, along with the winding wire filter, will prevail.

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