Glass Bead Filter Packs in Water Wells for Higher Efficiency and Reduced O & M costs

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Abstract The selection of poor quality natural sand and gravel filter pack media for water supply wells leads to insufficient hydraulics, increased well clogging, higher electrical energy demand, reduced life-cycle, and increased Operations & Maintenance costs. Extensive comparative field and laboratory studies since 2008 proved, glass bead filter pack wells can achieve two figure savings for O & M at enhanced well performance and lifetime cycles.

Keywords Alternativefilter pack media, physical, hydrological properties, well performance

Introduction

Until late 2007 gravel and sand were exclusively used as filter pack media in water wells. Gravel and sand are natural minerals, their availability and quality is rapidly declining in the last years. This phenomenon can be detected globally. Apart from that, even material in accordance with industry norms causes a lot of problems in well construction and functionality. For instance the German industry norm DIN 4924 which determines the specifications of mineral sands and gravel for filter packs in water wells accepts 1 % of unclarified particles, 12 % of undersized and 15 % of oversized particles.

The amount of undersized particles is growing during transport of the material to the construction site due to disintegration because of insufficient crushing strength. A summary of negative effects on well construction and performance is given by Hermann and Stiegler 2008. Among others the main problems are:

- Jamming and bridging because of angular and edged grain (Fig. 1)
- High share of undersized particles and fines
- Cost intensive development work with limited effects
- Reduced porosity and permeability of the filter pack
- Clogged filter packs and well screens with gravel debris

Examinations in the Netherlands first proved fines in gravel packs are a major source for well aging by clogging and enhancing microbiological scaling with iron and manganese (Van Beek & Kooper 1980, Van Beek 1995, DeZwart 2007). Further indications on influencing or promoting factors of pack media for well aging or scaling are given by Treskatis & Houben 2003. Precisely they namegrain shape, inner surface (coarseness), size, geometry and

Fig. 1 *Clogged well screen with gravel debris after development pumping*

volume of pore channelsand fines (from formation and filter pack).

With average operation times of more than 40 years, operation and maintenance costs for frequent well rehabilitation to restore capacity loss by scaling are a major financial burden in total lifetime costs of a well. In addition there are added investment costs for the substitution of irreversible damaged wells.

Alternative filter pack media which will avoid these problems were in high demand. First quality characteristics in order to achieve better and more sustainablewell performance were identified by Treskatis *et al.* (2009; Tab. 1).

With regard to these demands, glass beads seemed to be a natural choice for a test.

Alternative filter pack media

In late 2007 soda lime glass beads from Sigmund Lindner were first applied in a 150 m deep well in the FrankonianKeupersandstone near Nuremberg. Wells in that formation have to cope with severe and fast well aging by iron and manganese encrustation. Gravel filter packs in former wells were irreversibly destroyed after some rehab cycles with high impact hydromechanicalcleaning technics. Promisingresults from handling and well performance gave way to a series of comparative R & D projects.

Physical properties

A major R & D project, funded by the German Federal Ministry of Economics and Technology was conducted from 2008 – 2009. The authors, Treskatis *et al.* (2010), performed comparative laboratory tests of several sizes and variations of natural gravel and glass beads for the parameters (Tab. 2). With the result: "Glass beads have mechanical and physical advantages compared to natural filter gravels and can make an important contribution to avoid clogging and to reduce incrustations when used in suitable unconsolidated sediments and bedrock, and thereby to an overall reduction in desanding and regeneration expenses" (Treskatis *et al.* 2010).

Figs. 2 and 3 give a clear indication about the amount of differences in relevant properties between gravel and glass beads.

Characteristic of the material	Quality goals
Washed and free from 'undersized particles'	Low material losses free from 'undersized particles' and compaction when developing the well; reduction of the development time
Well- rounded gravel grains	Increasing the porosity and hydraulic permeability compared with the aquifer; reduction of the lowering and pressure losses; improvement of the development ability and yield
High quartz share	Avoidance of volume changes through swellable or broken minerals
Smooth surface	Minimising deposits
Low irregular form	Low demixing when filling; avoidance of pressure losses through colmation

Table 1 *Quality characteristics for filter pack media (Treskatis et al. 2009)*

roundness	peak-to-valley heights
specific weight	surface relief
bulk density	surface profile
grading	specific surface
breaking load during static stress	abrasion resistivity
breaking properties during static stress	chemical resistance to rehabilitation solvents
breaking properties during dynamic stress	abrasion resistance

Table 2 *Tested parameters*

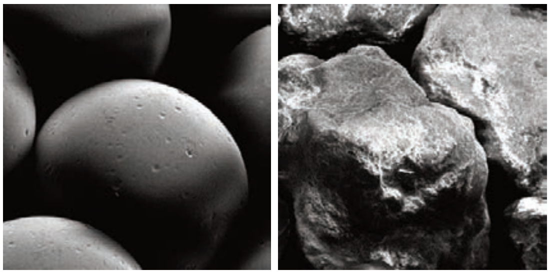


Fig. 2 *REM image of a glass bead compared to a filter gravel grain of the same grain size. The "smooth" surface of the glass bead prevents the formation of tensile stress whenload is applied and reduces the agglomeration of incrustations (Treskatis et al. 2010).*

Hydraulic and Hydrodynamic properties

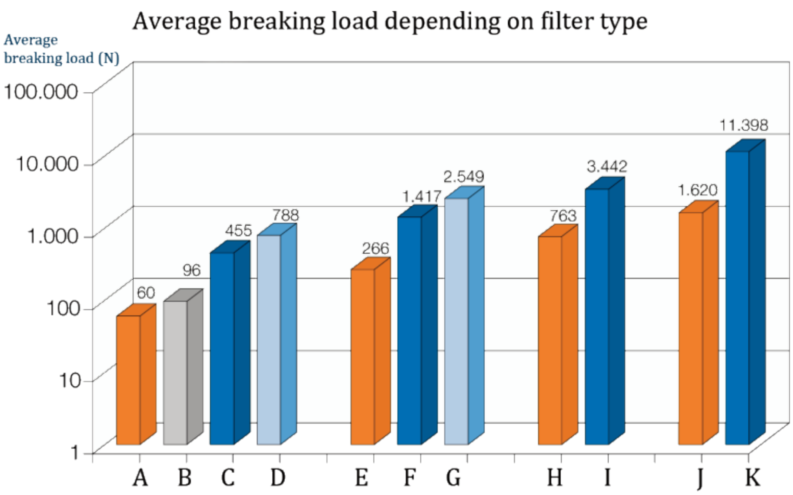
Comparative tests in the laboratory of Bau ABC (Federal Academy for Construction Professions) showed also better properties of glass beads for:

- Packing Properties/Compression Set
- Porosity
- Permeability

as well as better capabilities for sand discharge in the well development process at significantly higher efficiency. Glass beads generate a faster and, with regard to soil fines, more efficient sand discharge, while the limit of sand breakthrough, especially in uniform soils is already at a low leakage size. The grain larger than the characteristic grain is already mobilized on glass bead packs. Thus a comparatively rapid desanding is possible. A sand breakthrough occurs only when there is no supporting grain in the layer sequence. (Treskatis *et al.* 2011/2012)

Well aging caused by scaling

First column tests with gravel and glass beads in 2008 showed that in filter gravel, approx.



- A Filter gravel no.1 (1.4–2.2 mm)
- B filter gravel no.2 (1–2 mm)
- C glass bead type S (1.25–1.65 mm) part no.: 4505 #923033
- D glass bead type S (1.50±0.2) part no.: 4505-A #820029-1
- E filter gravel no.3 (2.0–3.15 mm);
- F glass bead type S (2.85–3.45 mm) part no.: 4511 #920032
- G glass bead type S (3.00±0.3) part no.: 4511-A #820022)
- H filter gravel no. 4 (5.6–8 mm)
- I glass bead type S (5–6 mm)
- J filter gravel no. 5 (8–12 mm)
- K glass bead type M (12 mm) part no.: 5018-99-24 #855057-20

Fig. 3 *Magnitudes of breaking loads for filter gravel and glass beads at different granulations and bead sizes and mixtures at static load handling (TRESKATIS et al. 2010)*

40 % more iron mass was embedded than in glass beads. Thus a clearly lower incrustation tendency could be expected in actual wells when using glass beads as filter pack media (Treskatis *et al.* 2009). Recent tests by the author *et al.* with actual wells in a test field and an extended laboratory set up with real heavy ferrous and manganiferousgroundwater proved that scaling of glass beads is delayed by factor 2 – 3 compared to natural gravel. The results will be published in late spring 2013. Fig. 4 shows the development of filter resistance over time in gravel and glass bead filled columns as a result of reduced porosity due to scaling processes.

Field results

To date more than 3000 t of glass beads were used in more than 100 water wells in Germany, Italy and the USA, covering the whole hydrogeologic spectrum from unconsolidated to solid rock and various groundwater chemistry, proving the laboratory results described above.

Further observations from contractors, technical consultants and well owners are:

- Easy application, no bridging or jamming during filling process
- Consolidated bedding after filling, no subsidence compared to gravel
- Time and volume for sand removal and clear pumping is down to 10 – 20 % compared to gravel
- Reduced drawdown of water table compared to former well layout
- Higher specific capacity
- Lower tendency of scaling in filter packs in exchange for higher rates inside the well screen.
- Intervals between rehabilitation can be stretched, which means lower expenses for O & M (The first water well equipped with glass beads in the town of Rosstal, near Nuremberg, still has not to be rehabilitated. The predecessor well in the same geologic setting had to be rehabilitated between every two years to once a year).

Meanwhile also 2 dewatering wells for mines in Colorado, one of them over 1.220 m. deep, are equipped with glass beads. Even under these demanding conditions the positive experience with handling or better filling could be proved.

Economic aspects

Based on local conditions, the investment costs for glass beads are between 2 and 5 times higher than for gravel. Regarding total costs of wells the surplus is between 0.5 %and 5 % depending for example on depth, diameter, screened area. But material price alone is no indicator for the efficiency of a well. Wells are long term investments with lifetime cycles far beyond 40 years. Operating costs, primarily for electrical energy and rehabilitation after iron and manganese scaling are the essential factor for efficiency. Due to higher specific capacity and delayed scaling, glass bead wells imply cost saving potential for O & M which will

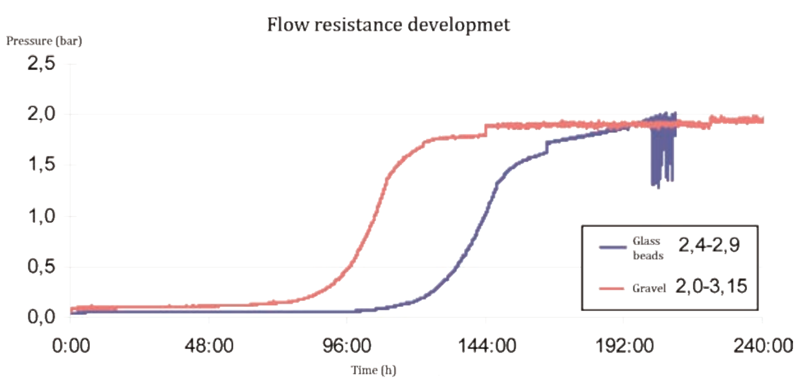


Fig. 4 *Pressure development in gravel packs 2.0 – 3.15 mm grading and glass beads packs grading 2.4 – 2.9 mm under continuous perfusion with iron and manganese containing groundwater*

more than compensate the initial higher investment.

Klaus & Walter 2011 did a first cost benefit analysis based on the then known facts. Even this first tentative approach on the base of 1 % savings for electric energy and 25 % for rehabilitation costs produced a total benefit of 8 % after 40 years considering interest and inflation.

Actual wells showed an increase in performance between 20 % and 300 % with corresponding savings for pumping energy. An updated calculation by Klaus & Walter 2012 brought savings for pumping costs between 50 and 80 % per year, which means a ROI in 3.5/8 years just on the base of cost savings for water pumping. A first extrapolation of the potential savings for rehabilitation based on the results of the recent scaling tests brings total lifetime savings up to more than 20 %.

Conclusions

Glass beads as substitute for mineral gravel in filter packs of water wells are successfully applied since 5 years. The field and laboratory results show, this application is a progress in well construction and shifts the state of the art to a higher level.

For the first time, physical, hydrological and chemical properties of a filter pack can stay consistent for the entire well lifetime cycle. Savings of electrical energy and O & M costs for rehabilitation are a major step towards real sustainability.

Promising results and positive feedback are coming also from the wastewater and water treatment sector.

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