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SUSTAINABLE BUILDING WITH CONCRETE: HOW LONG DO CONTAINERS LAST?

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ABSTRACT In the developed world there is a lot of concern that agricultural production, mainly livestock farming, may cause environmental damage. Any kind of livestock farming produces animal excrements. In Europe most animals are kept in buildings, the construction of slurry (and/or dung) storage is required. Generally, these containers are made of concrete. The most important question is, whether these containers are leak proof. Tests on the tightness of storage reservoirs were run by the former Institute of Production Engineering and Building Research (new name: see above). In particular, pressure tests according to DARCY were run. Another important question addresses the durability of the concrete. To assess this, two different methods, both according to DIN EN 12504-1 (former DIN 1048) were used: the rebound-hammer method and the hydraulic pressure test of drilling core samples (diameter 151 mm). For comparison, samples one year old and 72 years old were tested. It generally could be seen that the samples of very different ages matched perfectly with regard to additives and structure. The newest samples showed strength in the range of 25.0 to 35.0 N/mm², the average of the old ones was 27.4 N/mm². Thus, today's legal constraints on the quality of concrete for agricultural containers are fully covered also by a 72 years old container. Therefore, the technical service life of the container by far exceeds the depreciation period.

Keywords: Farm building with concrete, environmental safety.

INTRODUCTION Since many years there is a long-lasting discussion worldwide, whether agricultural production causes environmental damage of groundwater, soil and atmosphere. Of course this very much depends on the climatic conditions and the different types and sizes of the farms. The problem with animal farming is the environmental safe storage of slurry, dung, silage juice and cleaning water. As on most farms in Europe the animals are kept in houses, the building of storage reservoirs is needed. They are generally made of reinforced concrete.

Since many years there are complaints, that the procedures to get a building permission are complicated, they take too long and they are expensive.

Tightness and durability of concrete containers. The most important question by point of view of the authorities is, whether the containers are "tight".

The demands of the building permit procedure for dung storage plates with walls are the same which are valid for slurry and liquid manure. The most important regulations are the Water Act (Wasserhaushaltsgesetz), the new DIN 1045 and DIN 11622, which has also been reviewed. But, different from the permit procedures concerning slurry storage, the protection of the atmosphere is not considered in this case.

PENETRATION TESTS ON CONCRETE SAMPLES. The experiments described in this paragraph deal with the main question, whether concrete for agricultural buildings and facilities is "tight" in the sense of the law. This investigation serves to make the decisions of the building authorities easier, which will accelerate the permit procedures. In total 24 tests with samples of two different manufacturers were run. Table 1 shows the overview with the comparison of tests with pure water and with slurry of defined quality.

Table 1. Quality of concrete samples and their test purposes.

Manufac-turer	Sample no.	Concrete recipe	Concrete quality	with water	with slurry	range [N/mm]
L	1-3	41430.F	B25	3x	-	1-33
	4-6	41430.F	B25	-	3x	1-17
	7-9	61433.F	B35	3x	-	1-18
W	10-12	61433.F	B35	-	3x	1-10
	13-15	41430.F	B25	3x	-	2-28
	16-18	41430.F	B25	-	3x	1-13
	19-21	61433.F	B35	3x	-	2-12
	22-24	61433.F	B35	-	3x	1-20

The tests were run in accordance with DIN 1045. Figure 1 shows the split concrete sample after the test with water in the concrete quality B25.

The minimum penetration depth was measured with slurry at a pressure of 0.5 N mm^{-2} after a period of 72 hours, in concrete of quality B25. The results ranged from 0 (zero) to 18 mm. According to the demand of DIN 1045 ("Building with concrete") the average of three samples was calculated. The penetration with the same material of a better quality (B35) showed an average of 8 mm, which is 3 mm less. These results refer to the test blocks made by factory L.

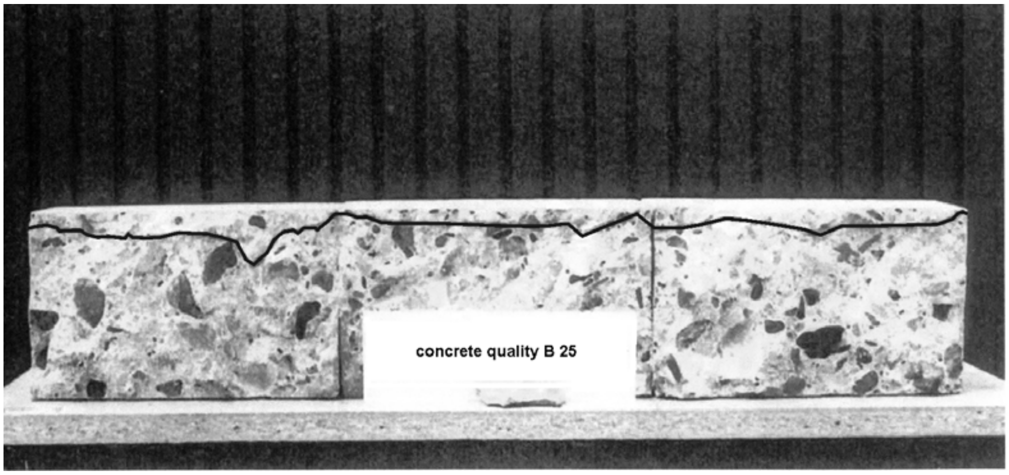

Figure 1. Split concrete test block after penetration test with water (2004).

The line shows how deep the fluids penetrated the samples. On the whole, the concrete test blocks did not allow passage of either water or slurry.
The tests also showed that slurry penetrates less deeply into concrete than water under equal conditions. On the whole, the ratio between the penetration depths measured with water and those measured with slurry was between 2:1 and 3.4:1; with a mean of 2.4:1. Thus the requirements of the German Water Act (WHG) on slurry containers are met (Krentler, 2008).
Now the question arises, how long these containers last.

MATERIAL. The Institute of Agricultural Technology and Biosystems Engineering of the vTI (Johann Heinrich von Thünen-Institut) in Braunschweig is situated on the area of the former Aeronautical Research Institute, built in the thirties of last century (Grube, 2003). This led to the idea to seek an old concrete container made at that time. In fact, two underground filling stations for high octane petrol for fighter planes were found by the drawing of an American reconnaissance plane pilot made in 1944 (Grote, 1994). No old plans showed them. To make sure, whether this was really a filling station the following trick was used: The very high octane figure (it was 120; today we normally have 95 for cars and 98 for propeller planes = Avgas) was reached by addition of lead – which for being poisonous is no longer allowed. If so, remainings of this lead should be found. The Julius Kühn Institute (JKI) in Braunschweig tested a seepage water sample from the groundplate of the concrete pit by ICP-MS, where they found 0,035 mg/l led. This shows

- there has been a small amount of lead; and
- this has not been the storage tank for highly leaded petrol

Thus, it was the bunker which had been sought for.

Figure 2 shows the plan of the filling station for high octane fuel made of reinforced concrete, with the position of the drilling core samples of two different sets.

METHODS FOR TESTING CONCRETE QUALITY. The most important quality to assess the durability of concrete is its prism strength in compression. To measure this two different methods are common in Germany; these are the non destructive method and the destructive method. Both methods are described in the technical standard DIN 1048, Part 2.

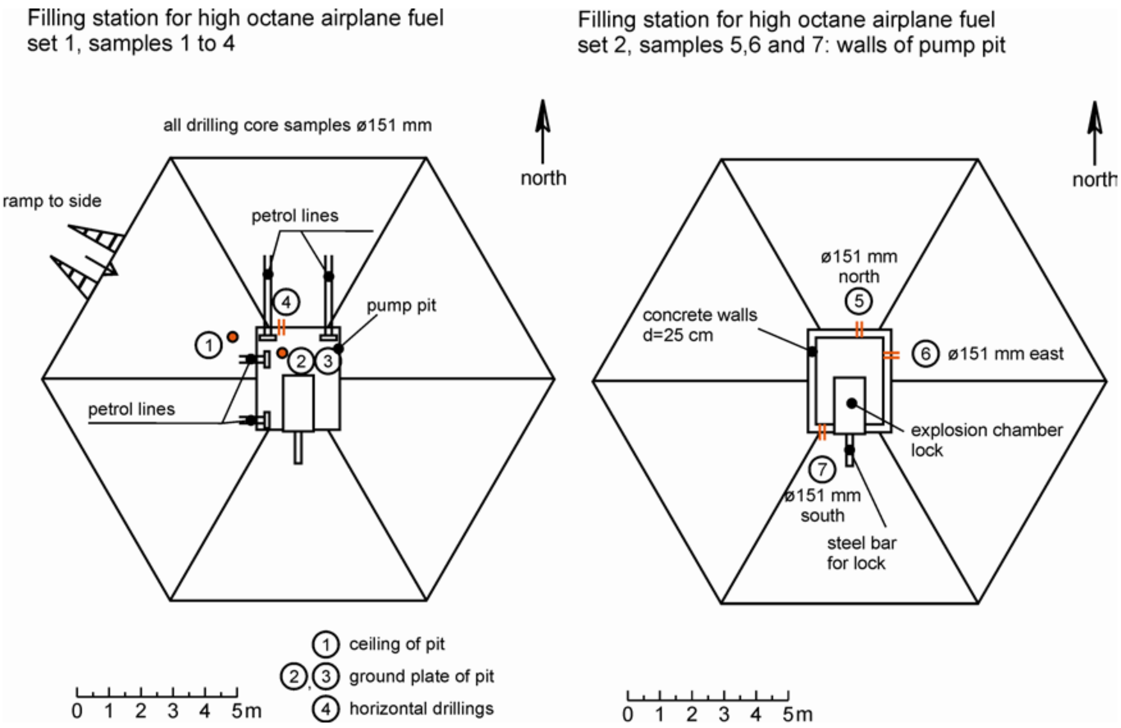

Figure 2. Filling station, made of concrete, for high octane airplane fuel.

a) The non destructive method. This method uses the quality of elasticity of concrete by using a rebound hammer (according to its inventor also called Schmidthammer). As the range of the results will be rather wide, statistical methods are needed. In this case four times 10 rebound tests are demanded. The rebound hammer works like this: a strong steel spring ejects a steel bar with diameter of 15 mm against the concrete to be tested. The elasticity of the concrete repels the bar to a certain amount. This can be read in a scale on the side of the tool. This value can be read in a table which shows the concrete quality equivalent. Next step is to add a correcting figure according to the angle under which the rebound hammer was used. In this case it was + 90°. For the correcting figures another table is available. This final value then indicates the concrete class, expressed in prism strengths in compression. Figure 3 shows the rebound hammer used for these tests.

Figure 3. Rebound hammer, also named Schmidthammer.

b) The destructive method. The destructive method for the determination of the prism strength in compression of concrete drilling core samples with different diameters needs a very strong drilling machine (figure 4). These samples can be taken vertically or horizontally as well by fixing the frame of the machine to the concrete wall or plate. In this case, the biggest possible diameter (151 mm) was used. This is advantageous for the later test of the prism strength in compression, as DIN 1048 part 2 demands samples which should be as wide as high. Figure 4 shows the drilling equipment of the Canadian company Karsten Fischer in Braunschweig, Germany, who made the drillings, just before start. On the construction site electric power of 240 [V] AC and a water hose for the cooling must be provided. The samples must then be equalized by a concrete saw (Betonsäge). Figure 5 shows three of the samples before cutting.

Figure 4. Equipment for taking drilling core samples.

Figure 5. Drilling core samples.

Finally, the cores were brought to the Institute for Building Materials of the Technical University of Braunschweig (MPA) in order to determine their prism pressure strength by using the hydraulic pressure test based on the technique commonly applied in construction.

RESULTS. The values of the tests with the rebound hammer showed a very wide range. They are just figures without physical explanation. The smallest one was 29, the highest was 41. This explains why such a high amount of tests is demanded by DIN 1048, Part 2. The correcting values were just 2 or 3, which is small. The conversion table of the regulation shows concrete classes of B15, B25 and B35. This means concrete prism strength of 15, respective 25 or 35 N/mm². The overall average is a bit better than B25, which sounds very reasonable. This concrete classification was valid for more than a half century, but it has been changed now into a "C"-classification. Table 2 shows the results in old and new classification.

Table 2. Test of 72 years old concrete container by the method of rebound hammer (Schmidthammer).

run	R	C	value	class (old)	class (new)
1	36	+2	38	B 35	C 30/37
2	32	+3	35	B 25	C 20/25
3	39	+2	41	B 35	C 30/37
4	32	+3	35	B 25	C 20/25
5	26	+3	29	B 15	C 12/15
6	28	+3	31	B 15	C 12/15
7	40	+2	42	B 35	C 30/37
8	36	+2	38	B 35	C 30/37
9	30	+3	33	B 25	C 20/25
10	26	+3	29	B 15	C 12/15
			R_m = 35 =>	B 25 or	C 20/25

with R = rebound value
C = correction value according to list "not horizontal"
value = value of rebound length
R_m = average rebound value

This table is one out of four as demanded by DIN 1048 part 2.

Table 3. Test of 72 years old concrete container by destructive method (drilling core test).

	measures					
no.	length [mm]	hight [mm]	h/∅	specific weight [kg/dm³]	max. quality diameter [mm]	quality [mm]
1	141.4	139.3	0.99	2.076	32	14.5
2	141.3	146.6	1.00	2.243	32	31.3
3	141.4	108.8	0.80	2.183	32	23.4
4	78.8	78.8	1.00	2.177	32	26.4
5	78.6	79.3	1.00	2.211	32	41.4
6	141.6	141.8	1.00	2.219	32	23.1
7	141.4	140.8	1.00	2.261	32	31.9
			average:	2.196		27.4

(When calculating the specific weight of the concrete the reinforcement was subtracted).

The destructive tests by using drilling cores are said to be more reliable and precise. For these tests the German standard DIN 1048 now migrated into the international standard DIN EN 12504-1. The results of the related tests were shown in the test certificate handed by the Material Testing Authority (MPA). The report says that the samples were cut wet to receive an absolute plain surface. During the pressure tests the samples were absolutely dry again. The storage period of the samples was 4 weeks at 20 °C and 65 % humidity. The results are shown in table 3.

The overall quality of the tests by the destructive method is 27.4 N/mm², which would be classified as a B25 (old) or C 20/25 (new). It can be stated that both test methods lead to the same result, with a very small difference of 1.4 N/mm² only. The comparison of the concrete quality of the 2004 sample (table 1) and that of the 72 years old container is nearly the same. Figure 6 shows the top of the old container how it looks today.

Figure 6. View of a 72 years old container made of reinforced concrete.

CONCLUSION. A comparison of the concrete samples from the 2003 penetration tests with those of the samples from the container of 1937 showed that they matched perfectly with regard to additives and structure.

Thus, both concrete types can be compared well. In both cases, Portland cement was used as a binder. The water-cement ratio in the samples from 2003 was 55 %. In the old container, this factor could not be determined. Generally, however, the desired ratio was 40 %.

In 2003, pressure strengths showed the qualities B25 and B35 (C20/25 and C30/37 according to the new classification). The 1937 samples were tested according to two different methods, which showed the same results.

Hence, even the 72-year old container fulfills the main requirement, namely tightness. Therefore, the technical service life of the container by far exceeds the depreciation period. This means for the future, that depreciation periods will not be decided by the engineers, but by financial aspects.

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