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Assessment of Water Blasted Concrete Structures
État de structures en béton, traités par jet d'eau
Beurteilung von wassergestrahlten Betonuntergründen

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SUMMARY

The use of a high pressure water jets is a normal procedure for preparing concrete substratae for repair. The concrete quality as well as the parameters for the high pressure water jet define the quality of the exposed concrete. This article presents the relationships between the parameters of the high pressure water jet and the concrete substratae, as well as an assessment of the treated concrete structure with regard to plainness, roughness and frequency of cracks.

RÉSUMÉ

La technique du jet d'eau à haute pression est un procédé habituel pour la préparation de structures en béton avant des travaux de remise en état. La qualité du béton de même que les paramètres concernent le jet d'eau ainsi que les conditions de chantier influencent la qualité de la réparation. L'article présente les relations entre les paramètres du jet d'eau et la structure traitée ainsi qu'une appréciation de la surface traitée ou de la fréquence des fissures.

ZUSAMMENFASSUNG

Die Hochdruckwasserstrahltechnik ist ein gebräuchliches Verfahren zur Vorbereitung von Betonuntergründen vor Instandsetzungsmassnahmen. Die Betonqualität sowie die betrieblichen und strahlseitigen Einflussgrössen bestimmen dabei die Beschaffenheit des Untergrundes. Im vorliegenden Beitrag werden Abhängigkeiten des hydrodynamischen Abtrages diskutiert, sowie eine Beurteilung des Traggrundes hinsichtlich Ebenheit, Rauheit und Risshäufigkeit vorgenommen.

1. INTRODUCTION

Since the beginning of the 1980's the use of the high pressure water jet technique in the building industry has increased significantly. This is due to the ongoing need for repair work on existing buildings coupled with advances in the standard of the technique itself. The high pressure water jet technique is now used in all cases where this method provides particular advantages, ranging from cleaning, roughening and removing to drilling and cutting. In carrying out concrete repair work for the preliminary treatment of concrete substrates, the water jet technique can be applied to remove concrete skin and weak concrete layers as well as solid concrete of any thickness to any range from small to large quantities. Precondition for optimal economic implementation of the high pressure water jet is a thorough knowledge about the removal mechanisms. The behaviour of the mechanisms is determined by specific working and tool parameters as well as the material mechanics of the substrate. In addition to the structure of the removed concrete the structure of the blasted concrete substrate is particulary interesting. So, it is inevitable to prepare an even, adhesive subsurface to enable a firm and durable bond between concrete substrate and the protective - or concrete substitution system which is placed on the top. The concrete substrate should not contain any cracks or delaminated concrete parallel to the surface and should possess sufficient roughness, strength and water content.

The following article outlines the range of scientific research that has been undertaken on the concrete behaviour when the high pressure water jet is used for repair work. Furthermore, results will be presented concerning the fulfillment of set requirements in the structure of the concrete substrate after treatment.

2. AIM OF RESEARCH

The investigation of operational and tool parameters is designed to procure the capacities for concrete treatment of the high pressure water jet in dependancy on the adjustable parameters. Operational parameters are i.e. jet distance and working speed, whereas the most important tool parameters are water flow and jet pressure which determine the jet speed. Different constellations of the mentioned parameters should optimize the technique in accordance to the individual requirements of each possible application situation.

The concrete substrate after treatment will be evaluated with regard to outer appearance, roughness and plainness of the substrate. Particular attention will be paid to the eventual initiation of cracks by the high pressure water jet.

3. OPERATIONAL AND TOOL PARAMETERS

3.1 Water flow and jet pressure

In Figure 1 the volume of removed concrete is shown in dependency on jet pressure and nozzle diameter. The volume of removed concrete in relation to time is of particular interest because this relation describes the capacity for removal in the field of concrete repair measures. A strong progressive dependency of the time related volume of removal on the nozzle diameter and jet pressure can be observed. The amount of removed concrete disproportionally increases at a pressure of 100 MPa in dependency on the nozzle diameter. This can be explained by an increase of the water flow caused by larger nozzle diameter in combination with high jet pressure. Furthermore, an investigation of the width of the notch, caused by water jet, shows that higher pressure and especially larger nozzle diameters lead to an enlargement of the notches. Now, on the one hand, this might be due to the fact that the water and removed concrete particles must leave the produced notch with clearly reduced speed. On the other hand, the deeper the notch the more material has to be removed while the slit width stays the same size. Both factors lead to a disproportionate widening of the notch and to a progressive concrete removal. As has been expected, an increase of the jet pressure from 100 MPa to 200 MPa by small nozzle diameters does not effect a significant rise in the volume of removed concrete because the water flow of the high pressure water jet increases at a considerably lower rate. Accordingly, the effectiveness of the water flow for concrete removal is more characterised by the nozzle diameter than by jet pressure.

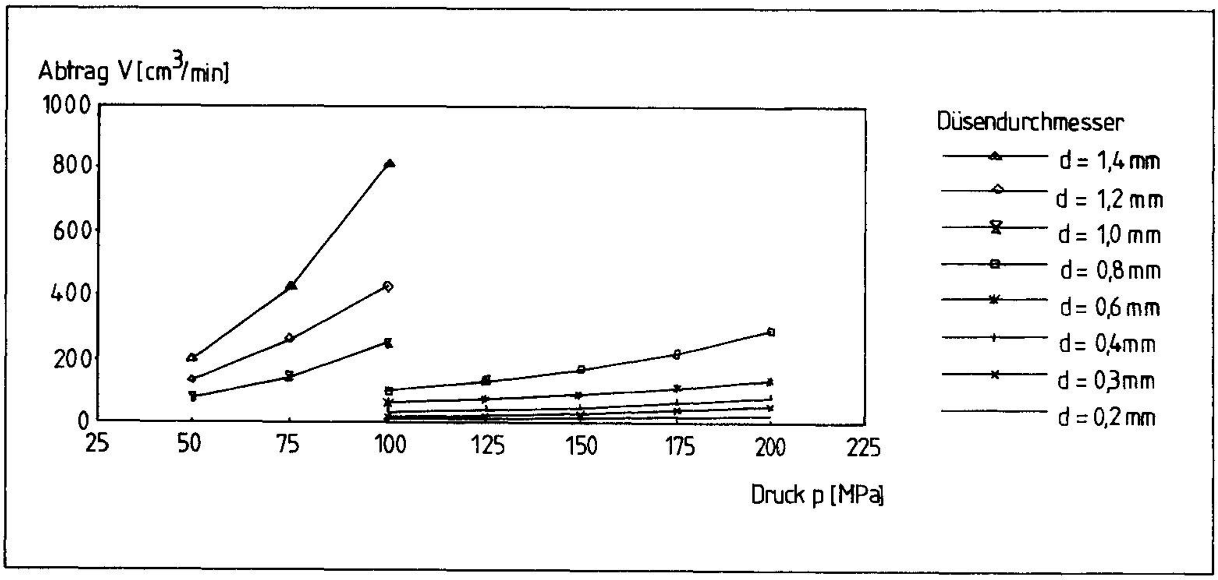

Fig.1 Volume of removed concrete (Abtrag) in dependency on jet pressure (Druck) and nozzle diameter (Düsendurchmesser).

Under economical considerations neither the jet pressure nor the nozzle diameter alone can account for a characterisation of the removal process. Here, it is necessary to additionally investigate the power expenditure. The power expenditure is the energy which is necessary to remove one measure of concrete. The specific removal energy, as the power expenditure is called in Figure 2, results from the ratio of jet capacity and the volume of removed concrete in time. The jet capacity is defined as the product of jet pressure and water flow. Figure 2 shows that a jet pressure of 100 MPa is the lowest power ependiture needed for the here considered concrete, independent of the nozzle diameter. Below and above this value the removal capacity is smaller. If a maximisation of the amount of removed concrete is another central issue, the largest nozzle possible should be used. The use of two or more small nozzles with the same power expenditure used for one large nozzle results in a smaller amount of removed concrete. But, the latter is advisable in those cases where no deep removal is desired, where the aim is a roughening of the subsurface [1].

3.2 Operational Parameters

In addition to the tool parameters, operational parameters as operational speed, distance and angle of jet can be changed. The most influental operational parameters for the removal capacity are jet distance and operational speed. With decreasing distance the removal capacity increases disproportionally. Especially when using small nozzles already minimal distance changes have a significent influence. Additional tests with varying distances and different nozzle diameters showed that for every nozzle diameter within an economically sensible pressure range the smallest distance was at the same time the most favourable and efficient one in energetic terms. The choice of high operational speed leads to a significant increase of the removed amount of concrete and, as expected, to a decrease of the depth of the removed lift. Furthermore, it can be observed that repeated passing over the same spot with a consistent stress duration and distance achieves a higher capacity for removal than a single pass with low operation speed. The jet angle, a further influental parameter, has almost no influence on the removal capacity when small nozzles are used, but with larger diameter a jet in advance has proved favourable.

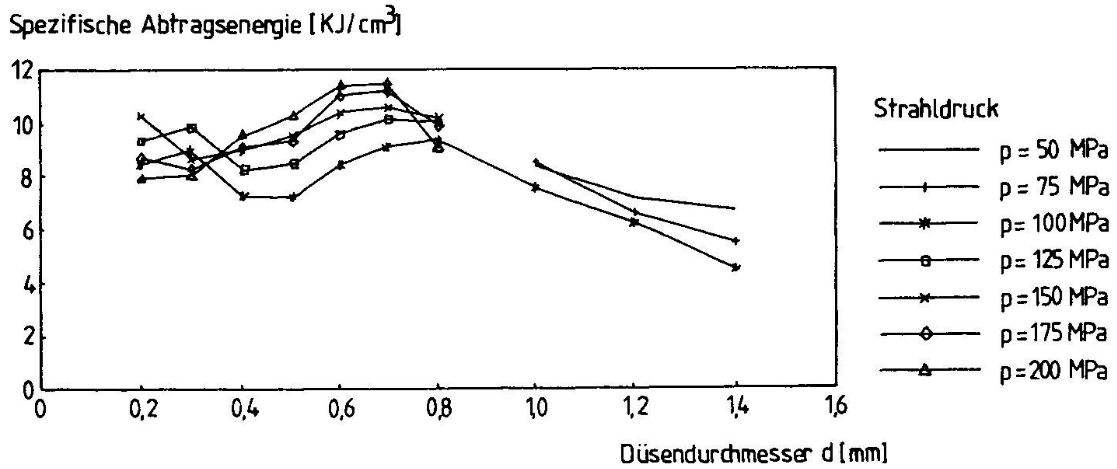

Fig.2 Specific removal energie (sp. Abtragsernergie) in dependency on jet pressure (Strahldruck) und nozzle diameter (Düsendurchmesser)

4.0 THE CONCRETE SUBSTRATE AFTER TREATMENT

4.1 The structure of the substrate

The preparation of the substrate prior to the placement of repair concrete and mortar or the protective system has to improve the strength, secure the compatibility and improve the bonding behaviour of the concrete substrate and the protective layer. Therefore, the remaining concrete substrate should not contain any cracks or delaminated concrete running parallel to the surface, or shell shaped in the surface ambient. It should, furthermore, be of sufficient roughness and strength [2]. If removal work on decayed concrete is carried out, it has to be regarded that not too much material will be removed by the implemented technique and the remaining concrete will not be damaged. When using the high pressure water jet technique the profile of the remaining concrete is determined by a complex set of interrelated parameters. A geometrically exact removal is impossible with this technique. This can be put down to the high pressure water jet's working mechanisms. So, the resulting surface after removal is mostly determined by the strength of the concrete substrate. In consequence, after a treatment by high pressure water jet the substrate is uneven but usually very strong. Depending on the individual concrete's structure one has to reckon with crates as deep as or even many times deeper than the nominal depth of the layer to be removed [3]. With increasing strength of the concrete, shell like delaminations appear more often, whereas the depth of removal decreases. As the cementing material poses small resistance to the water jet, the breaking off of large parts occurs very seldom. Rather, only the grains are washed clear, which in turn leads to a smaller time-related removal amount. If the cement stone is of a relatively high strength and if furthermore a strong compound between cement stone and concrete aggrergate exists, one can expect a more grain-breaking removal. With less concrete strength the preferred technique is to remove the cement stone because of the different strength values of cement stone and concrete aggregate. This results in a more grain surrounding removal.

4.2 Plainness and Roughness

Until now, there have existed no standardized criteria for the evaluation of roughness or evenness of concrete substrates after treatment. An examination of evenness follows, therefore, the DIN 18202 [4]. Concrete substrates treated with high pressure water jet serve as testing samples. The removed concrete has to be of a nominal depth of 20 mm. For the evaluation of the relief a length of 100 cm is taken as a basis. As a comparative basis, in accordance with the DIN 18202, a line above the remaining peaks is chosen which is gained by laying a screed onto the treated substrate.

Meß-punkt cm	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm	7 mm	8 mm
0	7	51	5	18	53	5	23	35
10	0	21	15	12	46	8	31	47
20	29	15	33	25	48	23	30	31
30	25	26	29	30	22	28	23	23
40	27	7	21	18	33	24	20	45
50	29	14	48	8	24	0	12	14
60	38	35	17	33	12	14	18	18
70	7	17	26	33	14	30	2	20
80	27	22	18	22	17	17	7	18
90	19	20	17	13	18	14	11	14
100	41	7	13	4	7	12	7	10
Mittel-wert	24	19	19	19	22	27	15	22

Table 1 Profiles for examination the evenness

Starting from this basis in intervalls of 10 cm the distances between screed and concrete substrate are measured. The results of 8 sections are shown in table 1. Distinctive features for the substrate-surface after treatment are created landscapes with extreme peaks and hollows. The extreme values vary between 0 and 53 mm. The mediate values of the analysed sections range from 15 to 27 mm and are situated close to the nominal depth of 20 mm. Such variations of the depth of the removed concrete are to be considered normal with the high pressure water jet technique. They can be put down to the selective way of removal of the water jet and finally to the inhomogeneities within the concrete strength.

The roughness of the substrate is evaluated visually. It is understood that roughness of the substrate is the profile of remaining concrete in the small range of a few millimeters. A surface as rough as possible is aimed at, to achieve a strong bond between substrate and concrete-substitution or protective system. To achieve a rough surface the grain breaking method of removal is the better method than the grain surrounding one, because the latter one procures smooth stonesurfaces. Via an estimation of the crushed grain portion of the concrete substrate an evaluation of roughness can be undertaken.

4.3 Crack Investigations

For microscopical investigations field and laboratory concrete cores were taken before and after concrete removal by a high pressure water jet. These sample cores were impregnated with fluorescent resin, so as to avoid any cracking due to the sample preparation. With each thin section one to two cracks due to the removal technique could be detected on a length of 50 mm. The cracks are between 0.5 mm and 2.5 mm deep, 2 to 10 mm long, and between 5 and 15 micrometers wide. Most of the cracks run parallel to the surface structure of the cement stone, are grain surrounding and branch off with increasing depths. The examination shows that there are only a few crack initiations caused by the water jet technique. But, it has to be mentioned that the investigations took into account only one class of concrete strength. During current research uncertainties and contradictions arose concerning the crack initiation, when dealing with concrete of higher strength. So, the macroscopical appearance of concrete substrates with high strength hints a significant development of cracks which could not be detected with concrete of a low strength. Bazong [5] also reports on the development of cracks due to the treatment with the high pressure water jet and the resulting decrease of the adhesion properties. A clarifying, more detailled microscopical investigation of concrete after treatment which takes varying degrees of strength and further features into account has still to be carried out. Therefore, enhancing investigations on the structure of the concrete substrate after treatment with high pressure water jet are in planning.

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