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Experimental study for the connection process of new structures with old structures by channel and pipes for wastewater treatment plant structure

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A B S T R A C T

A Structure of wastewater treatment plant is a facility in which a combination of various processes (e.g., physical, chemical and biological) are used to treat wastewater and remove pollutants. Almost the design of wastewater treatment plant structure include two or more stages of construction, based on the capacity of the plant that its related mainly to the income sewage calculated for the population of the city at that time. Future works including many structures that will increase the capacity of the plant on the same area. That's will need to connect the new structures to the main system by pipe lines and channel. The objectives of this research are to study the connection process and activation of new structure and old structure of wastewater treatment plant, to provide an advice to the method of connection and carry out that connection experimentally with the engineers supervised that works, and to inspect and record the structural information for six months after complete the connection and starting the works with the future structures. The proving the accuracy of adopted method was done by nondestructive test carried out before and after the connection works. The results of construction and inspection shown that the new constructed concrete appears good compressive strength which is reached to 47.45 MPa that will be factored to increase the durability of concrete that being in touch with sewage.

Selection and peer-review under responsibility of the scientific committee of the 3rd International Conference on Materials Engineering & Science.

1. Introduction

Upon the request of the resident engineer office of wastewater treatment plant of Al-Mameera city, Babylon – Iraq, to present a study for connecting new ductile and steel pipes on already constructed structures (concrete tanks, concrete channel, and Manholes). Usually wastewater treatment is a multi-method used to change wastewater into an effluent that can be came back to the water cycle with lowest amount impact on the environment, or straight reused. The term is called reclamation of water because treated wastewater can be used for other objects. The treatment process carried out in A Waste Water Treatment Plant (WWTP), regularly referred to as a Water Resource Recovery Facility (WRRF).

The treatment plant concern by this study was constructed before about 40 years ago, with two stage of construction based on the estimated increase of population of Hilla city (The center of Babylon Government – Iraq). First stage of construction included the main building and tanks they allow the processing of treatment sewage and rain water and satisfy the design requirements at that time. Second stage of construction included adding more tanks and connection these new structures with the old by channel and pipes. The main target of this study is to present the best solution that can connect the new pipe lines in the old concrete tanks and makes it as one unit with preventing any leakage and causing any future defect on the old structures.

This paper present a suggested method to connecting new constructed pipe line on an old constructed structures with maintaining overall structure safety and stability without causing and defect to the old structures. Further on that, several nondestructive testing were carried to check the old structure before working and after connecting, and monitoring for more than 6 months to ensure the adequacy of the adopted method of connections.

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2. Literature review

P. Santos, E. Júlio (2008) described the study with an indication of its relationship to the current study using a laser roughness analyzer that was developed to characterize the roughness of the concrete substrate. Where the bond strength at the interface between concrete layers cast at different times is significant to make sure the monolithic actions of reinforced concrete composite parts. The suggested new method presents four main advantages which are including the increasing correctness, it is easy and fast to execute, it implies a really non-destructive method, and the results can be evaluated in field [1]

Santos and Júlio (2011) presented an experimental study used to evaluate the effect of shrinkage degree of difference and stiffness on the bond strength of new-to-old concrete interfaces. Both factors were shown to have a important effect on the bond strength and failure mode of concrete-to-concrete interfaces [2].

E. Piancastelli et al. (2014) focused in their paper on the classification of the interface bond and compatibility between UHPC and normal concrete. The program of tests was conducted in the spirit of ASTM, because there are not standard test methods currently be present for UHPC. In adding up, a sequence of mathematical models were developed to support the results obtained in the experimental investigations. The results highlight the exceptional performance of the bond, but they also show a number of challenges with admiration to characterizing the bond [3].

E. Piancastelli et al. (2017) published a paper where they write the most important features and results of an experimental study to establish the bond strength between the concrete of a column of an existing structure (old concrete) and the concrete that will be used in its strengthening project (new concrete). For the bond strength tests, a specimen was considered, this is called double sleeve specimen. The bond strength results obtained from the tests using double sleeve specimens, called Double Sleeve Tests, were compared to the results obtained from using the Slant Shear Test [4].

Further researches around this topic might be founded in references such as Haber, et al. (2016) [5], D. Varga, and B. Graybeal (2014). [6], and ASTM C496 (2011) [7], ASTM C882 (2013) [8], ASTM C39 (2015) [9].

More of that, many researchers works on the connection of concrete to concrete or concrete to another material and provide good bond, but there are no specific study deal with that experimentally an present a recommendation advice to do that in its accurate way. So, this study consider that by stating a method and check its applicability.

3. Data collection and evaluation

Upon the first site visit of the project (second stage – Extended parts), a collection of data started based on the drawing and specifications of the works provided by the resident engineer staff and their manager. All old structures involved by the study was constructed before about 40 years ago, while another new tanks and channels are constructed nowadays. Most of the connection was under ground level, and others were above ground level.

The main design was prepared to satisfy a specific capacity that within the calculation increased after 30–40 years and second stage must start. Future works in the second stage included more concrete tanks. For the activation of the new design with new structures need to connect the new one with the system by pipe

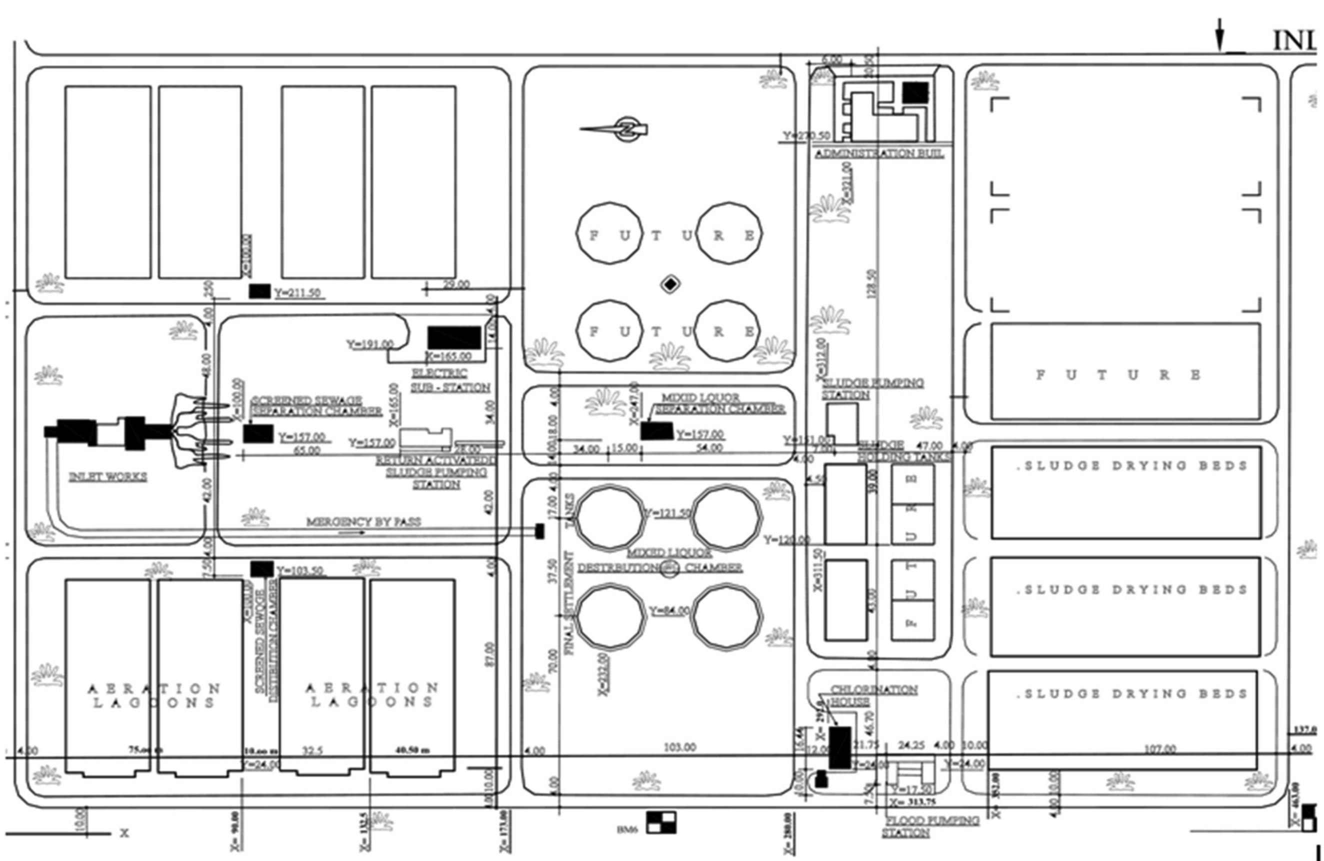

Fig. 1. Site layout of west water treatment plant structure.

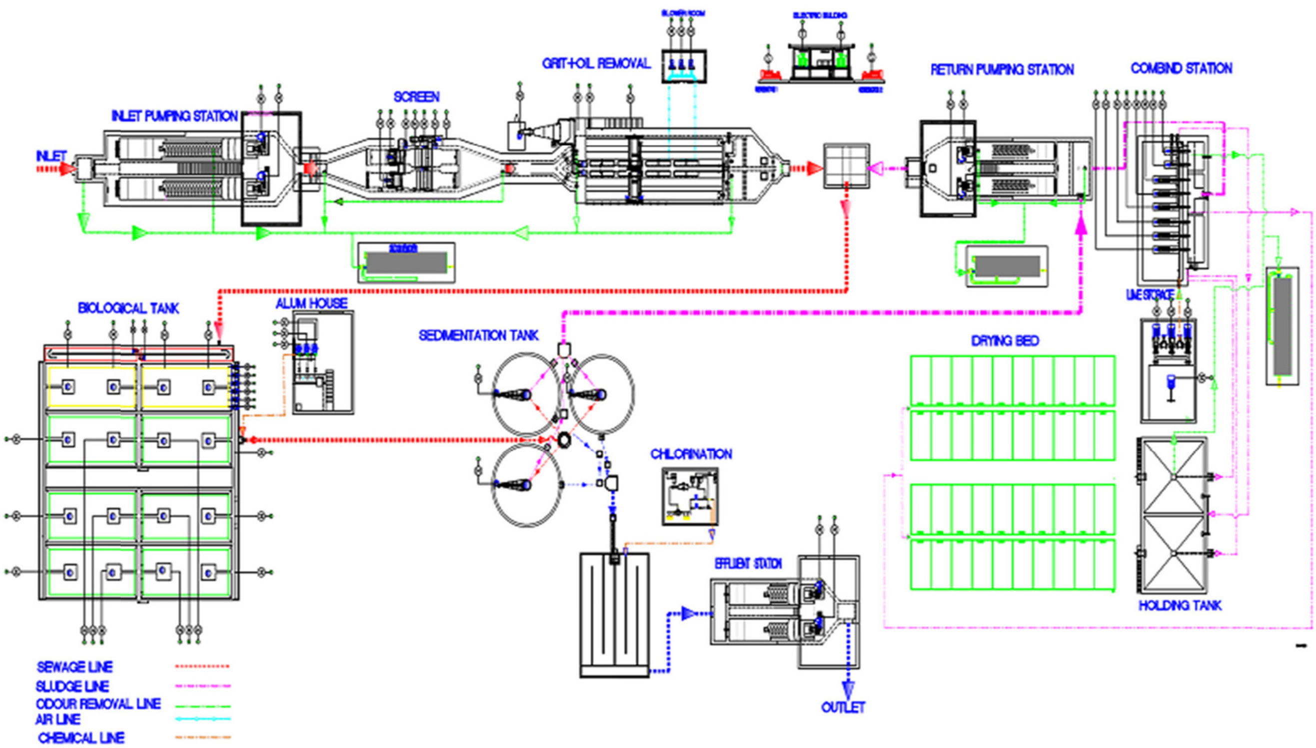

Fig. 2. Pipe connection and layout of wastewater treatment plant.

lines and channel, which is the subject of this research study, as shown in Figs. 1 and 2. The locations (points) from which data were collected are selected within old and new connected area to investigate the difference between compressive strength for old and new concrete.

The most important data was the evaluating the concrete of old structures, recording their fulfillment with the construction requirements and at this age. That was done by carrying nondestructive test (Ultra-sonic and Schmidt Hummer test) to prepare a report that shows the field compressive strength. Where its results revels that the concrete satisfy the requirements by compressive strength more than 30 MPa which, its indicates that these structures are acceptable constructively. Table 1 shows the Ultra-sonic and Schmidt hummer test results for sludge pumping station, Table 2 shows the Ultra-sonic and Schmidt Hummer test results for screen sewage separation and distribution chamber, and Table 3

Table 1
Ultra-sonic and Schmidt hummer test results for sludge pumping station.

Sludge Pumping Station points	Wave Velocity	0.53 * V	EXP(0.53 * V)	Ultra-Sonic Test (MPa)	Schmidt Hummer (MPa)	Average (MPa)
1	4.9	2.597	13.4234	37.59	32	34.79
2	4.7	2.491	12.0733	33.81	32	32.90
3	4.94	2.6182	13.7110	38.39	33	35.70
4	4.61	2.4433	11.5110	32.23	35	33.62
5	4.68	2.4804	11.9460	33.45	34	33.72
6	4.78	2.5334	12.5963	35.27	36	35.63
7	4.69	2.4857	12.0095	33.63	32	32.81
8	4.89	2.5917	13.3525	37.39	36	36.69
Average				35.22	33.75	34.48

Table 2
Ultra-sonic and Schmidt Hummer test results for screen sewage separation and distribution chamber.

Screen sewage separation and distribution chamber points	Wave Velocity	0.53 * V	EXP (0.53 * V)	Ultra-Sonic Test (MPa)	Schmidt Hummer (MPa)	Average (MPa)
1	4.87	2.5811	13.2117	36.99	34	35.50
2	4.85	2.5705	13.0724	36.60	34	35.30
3	4.82	2.5546	12.8662	36.03	30	33.01
4	4.92	2.6076	13.5665	37.99	34	35.99
5	4.75	2.5175	12.3976	34.71	36	35.36
6	4.67	2.4751	11.8829	33.27	32	32.64
7	5.12	2.7136	15.0835	42.23	33	37.62
8	4.55	2.4115	11.1507	31.22	33	32.11
Average				36.13	33.25	34.69

Table 3
Ultra-sonic and Schmidt Hummer test results for mixed liquor distribution and separation chamber.

Mixed liquor distribution and separation chamber points	Wave Velocity	0.53 * V	EXP (0.53 * V)	Ultra-Sonic Test (MPa)	Schmidt Hummer (MPa)	Average (MPa)
1	4.46	2.3638	10.6313	29.77	32	30.88
2	4.49	2.3797	10.8017	30.24	32	31.12
3	4.51	2.3903	10.9168	30.57	33	31.78
4	4.48	2.3744	10.7446	30.08	35	32.54
5	4.62	2.4486	11.5721	32.40	33	32.70
6	4.59	2.4327	11.3896	31.89	33	32.45
7	4.66	2.4698	11.8201	33.10	37	35.05
8	4.55	2.4115	11.1507	31.22	33	32.11
Average				31.16	33.50	32.33

shows the Ultra-sonic and Schmidt Hummer test results for mixed liquor distribution and separation chamber. All tests for the structures are before the connection process carried out. The Schmidt Hummer test was performed in a vertical direction on concrete surface.

4. Site inspection

Site inspection of the tanks structures shows that the walls that must be penetrated have a thickness between 30 and 40 cm. More precisely, the location of connection was within the ground level or underneath. The inspection on these tanks shows several location that already defected by long time of using and from the sewage effect, where these area must be treated within the overall repairing process.

5. Method of connection

The works started by emptying the tanks from sewage and start cleaning the structure from all sedimentations and others attached materials, specially at the location where penetrations need. All area was monitoring carefully, to check and defect occur due to penetration process and for preventing any further deficiency. Processing of penetration started by jack hammer (small size), all around the area of the pipe diameter +15 cm for allowing pipe inserting inside the tanks concrete wall. All works done cautiously and slowly with supervising and monitoring.

Provide technical advice on the first part from the study, which deals the opening of the old concrete walls and prepare connection areas, and the mechanism of dealing with old constructed parts to ensure its safety. To ensure adequate adhesion between old and new concrete, it was recommended to use special materials called (Nitobond EP) to complete the bonding process. That was after the old concrete was cleaned by air and forced water jet, and then dried for a while.

The recommended Nitobond EP material is epoxy resin primer, with higher strength bonding agent to bond concrete substrate to repair mortars. For connecting fresh wet cementations materials to existing cementations surfaces and provide full bond between them. Also, it utilize on vertical or horizontal planes where mortar or concrete can be supported by formwork. It is lengthy life creates it appropriate for using with formwork or where further steel reinforcement has to be fitted. The product is perfect for pavements, roads, loading bays and factories, bridges, and for bonded or granolithic floor toppings. It is equally suited to internal and external applications, and may be adopted as element of a repair system where a substrate/repair barrier is required or where the substrate is probable to stay everlastingly damp or wet.

The recommended Nitobond EP is formed on solvent open epoxy resins including colors and fine fillers. It is provided as a two elements materials in pre-weighed quantities for ready onsite mixing and using. Colored components - white base and green hardener – supply visual confirmation that satisfactory mixing is completed. Nitobond EP is designed with an overlay time of 10 h at 200 C, 6 h at 300 C making it additional suitable for using where additional steel reinforcement and formwork has to fit or where temperature is high. The minimum application temperature for Nitobond EP is 100 C.

The bonding agent should keep on in low situation after application for a minimum period of 6 h at 300 C. According to BS 6319pt 4, there shall not be bond failure of the sample when tested by slant shear method, with M30 concrete.

The recommended Nitobond EP can be applied by brush and it have a lot of advantages such as:

- Enables to put the concrete up to 6 h after applying Nitobond EP, without risk of delaminating
- Bond strength is more than the tensile strength of good value concrete
- Take actions as a barrier coat to the migration of chloride ions from host concrete.

5.1. Preparation

All surfaces of structures must be firm, have not dust and they are clean. Also, laitance should be take away by design with wire-brushing. The obtainable concrete have to be chipped to a sound substrate. All surfaces that are infected with oil or grease, adopt an method of removing by using a strong industrial detergent or organic degreaser. Surface should be washed thorough with water and dried before the application of selected Nitobond EP.

5.2. Mixing

The complete contents of the hardener can be poured into the resin container and two materials thorough mixed until a regular color is obtained. To make simple using at temperatures under 100 degree, the dividing parts should be warmed in hot water to a maximum of 250 degree before mixing. Fig. 3 shows the mixing process of the recommended materials.

5.3. Coating

For coating process, the mixed Nitobond EP should be brush applied to the arranged surface. New concrete should be place on within 6 h at 300 degree to the Nitobond EP coated substrate, when it is in a nasty condition. To ensure the adhesion of new concrete around the pipe and to ensure the elimination of cracks and capillary holes and small holes resulting from the casting process, it was recommended to use a specialized material called (Rendroc LA) for this purpose with the documentation of the mechanism of use, which will ideally treated the connection area between the pipe

Fig. 3. Mixing the recommended materials.

and surrounding concrete and significantly reduce the leakage from those areas.

Renderoc LA shrinkage compensated, is considered for large volume repairs typically more than 50 mm deep. Generally, This product can be used in sections up to 150 mm thick even though greater thickness may be achievable dependent on the configuration of the repair location and the volume of exposed reinforcing steel.

- This material have many advantages that makes it a the best choice like:
- It can give maximum compatibility with concrete of compressive strength 30–60 MPa
- This material shows dual expansion system compensates for shrinkage in the plastic and hardened states
- Low alkali content that minimizes risk of alkali-silica reaction
- Excellent bond to concrete substrates with no independent primer
- Appropriate for placement by pumping or pouring techniques into restricted places
- Displaces air without vibration and self-compacting nature eliminates honeycombing and its contains no chloride admixtures
- maximum protection against carbon dioxide and chlorides came from its high strength and low permeability.
- It can be prepared just required a site addition of clean water.

Fig. 4. Final surface around the connection area.

To ensure that there is no leakage from the connection parts of the pipe with the surrounding concrete, it is recommended to use specialized swelling agents called (Swell-able water-stops for in-situ concrete) to prevent the seepage. Swelling agents are hydrophilic cross linked polymers, that swell from 10 to 1000 times their own weight when located in an aqueous medium. According to their swelling properties, these materials have been subjugated in developing three different classes of materials in pharmaceutical industries, i.e. swell-able matrices, super disintegrates and swelling devices [10]. Almost this material was look like a thick tape stick over the outer side of the pipe before concreting. This rubber tape has enough flexibility to cover all outer circumstances of the pipe and swell when leakage start to close all voids and prevent water from leak. The Swell-able water-stops for in-situ concrete is an integral sealing for construction joints in concrete cast in-situ, Convenient and problem solving in situations where a conventional water-stop would require complex shuttering. Usual uti-

Fig. 5. Connection area left uncover for long time inspection.

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Table 4
Ultra-sonic and Schmidt hummer test results for sludge pumping station.

Sludge Pumping Station points	Wave Velocity	0.53 * V	EXP(0.53 * V)	Ultra-Sonic Test (MPa)	Schmidt Hummer (MPa)	Average (MPa)
1	5.2	2.756	15.7368	44.06	42	43.03
2	5.6	2.968	19.4530	54.47	44	49.23
3	5.5	2.915	18.4488	51.66	45	48.33
4	5.8	3.074	21.6282	60.56	43	51.78
5	5.9	3.127	22.8055	63.86	49	56.43
6	5.5	2.915	18.4488	51.66	48	49.83
7	5.4	2.862	17.4965	48.99	42	45.50
8	4.9	2.597	13.4234	37.59	46	41.79
Average				51.60	44.88	48.24

Table 5
Ultra-sonic and Schmidt Hummer test results for screen sewage separation and distribution chamber.

Screen sewage separation and distribution chamber points	Wave Velocity	0.53 * V	EXP (0.53 * V)	Ultra-Sonic Test (MPa)	Schmidt Hummer (MPa)	Average (MPa)
1	5.5	2.915	18.4488	51.66	46	48.83
2	6	3.18	24.0468	67.33	46	56.67
3	5.4	2.862	17.4965	48.99	47	48.00
4	5.4	2.862	17.4965	48.99	45	47.00
5	5.2	2.756	15.7368	44.06	46	45.03
6	4.8	2.544	12.7305	35.65	48	41.82
7	6.1	3.233	25.3556	71.00	45	58.00
8	5.6	2.968	19.4530	54.47	49	51.73
Average				44.45	44.50	44.47

Table 6
Ultra-sonic and Schmidt Hummer test results for mixed liquor distribution and separation chamber.

Mixed liquor distribution and separation chamber points	Wave Velocity	0.53 * V	EXP (0.53 * V)	Ultra-Sonic Test (MPa)	Schmidt Hummer (MPa)	Average (MPa)
1	4.9	2.597	13.4234	37.59	43	40.29
2	4.8	2.544	12.7305	35.65	43	39.32
3	4.6	2.438	11.4501	32.06	45	38.53
4	5.3	2.809	16.5933	46.46	42	44.23
5	5.1	2.703	14.9244	41.79	48	44.89
6	5.8	3.074	21.6282	60.56	46	53.28
7	5.2	2.756	15.7368	44.06	47	45.53
8	5.7	3.021	20.5118	57.43	42	49.72
Average				44.45	44.50	44.47

lizes include secant piled and diaphragm walled basements, pile caps and casting against old concrete. The super-cast SW range consists of swell-able water-stops. Super-cast SW formed sections, Super-cast SWX gun-applied paste and Super-cast SW adhesive and it can provide simple solutions to detailing pipe entries, construction joints in the vertical plane and to kicker joints. Also it increases in volume up to a maximum of 200% and it provides resistance to hydraulic pressure [11]. They can be linked to super-cast PVC water-stops to give an appropriate effective combination of water-stops which maintain network continuity.

All wall area that has been opened should be painted using epoxy materials of the same type used on the old structure. In the same time, a recommendation given to leave these area uncovered, to be checked within a prepared schedule. Fig. 4 shows the final surface area around the pipe that must be leave uncover.

The research continue to six months, from May to November by checking all connection area for any defects or leakage as shown in Fig. 5 where this area left uncovered for long time inspection. Again nondestructive tests carried to check the strength of the connection and the situation of the new concrete.

6. Results of compressive strength after connection

The results of non-destructive tests shows good compressive strength for the area of connection and no leak appear all the time of the six months. Tables 4, 5, and 6 shows the results of the Ultra-Sonic test and Schmidt hummer for the three sample tanks. These results were almost the same for the rest of connection, and similar behavior show overall the inspection time. On an average the compressive strength of the new concrete was 47.45 MPa, where that range helped to increase the durability of concrete on these tanks specially with the existence of sewage and its effect on the concrete on the long run.

7. Conclusions

The conclusions of this study are:

1. This paper present a suggested method to connecting new constructed pipe line on an old constructed structures with maintaining overall structure safety and stability without causing and

defect to the old structures. Waste water treatment plant of Al-Mameera city, Babylon – Iraq was selected to present a study for connecting new ductile and steel pipes on already constructed structures (concrete tanks, concrete channel, and Manholes).

2. Field works need special skill and from the important to study all factors effected and related to the main job. Herein in this research paper an experimental works done for more 30 days on the connection between new constructed structures with an old one, and more six months on inspection and recording, that in final give the proper advice to carry out this job accurately.
3. Materials recommended in this research was chosen carefully to achieve the main function effectively and provide a successful bond connection between new and old concrete and between concrete and pipe.
4. The results of non-destructive tests shown that good compressive strength for the area of connection and no leak appear all the time of the six months. These results were almost the same for the rest of connection, and similar behavior show overall the inspection time. On an average the compressive strength of the new concrete was 47.45 MPa, where that range helped to increase the durability of concrete on these tanks specially with the existence of sewage and its effect on the concrete on the long run.

CRediT authorship contribution statement

Ali Fadhil Naser: Formal analysis, Writing and Editing. **Hussam Ali Mohammed:** Methodology, Project administration, Resources. **Ayad Ali Mohammed:** Investigation, Methodology, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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