

Evaluation of Chezy Coefficient on Concrete Trapezoidal Channel Strengthened By CFRP Sheets

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ABSTRACT_ Carbon fiber reinforced polymers (CFRP) were widely used in strengthening reinforced concrete members in the last few years due to advantageous properties such as light weight, corrosion resistance, and smooth surface and high strength. This study is to investigate the flexural behavior of reinforced concrete trapezoidal channels strengthened with CFRP sheets inside the channel, and evaluate the effect of CFRP sheets on the flow, especially on Chezy coefficient with different discharges. The research is conducted using four specimens of trapezoidal channels. It is 45 cm bottom wide, 40cm depth, 60° side slope and the length is 160 cm depending on the best hydraulic section for trapezoidal channel. the channels are linked together to be flume with length (6.4m) and then three different cases of channels are investigated with five different discharges to find the Chezy coefficient for each case. From experimental data and curvatures found that Chezy coefficient (c) is increased with increasing ratio of CFRP sheets to concrete. Finally, a series of flexural tests were conducted on reinforced concrete channels. One is controlled channel and other three channels were strengthened. We found that the externally bonded CFRP sheets have increased the stiffness and maximum load of the channels and the cracks and the deflections have decreased for strengthened channels.

Index Terms— strengthening, CFRP sheets open channels, trapezoidal, Chezy coefficient, concrete

1 INTRODUCTION:

Concrete is one of the important materials being used in civil applications. It is being used to serve a variety of structures such as hydraulic, residential, and industrial structures. Reinforced concrete structures often have to face modification and improvement of their performance during their service life. A large number of structures constructed in the past using the older design codes in different parts of the world are structurally unsafe according to the new design codes, Infrastructure decay caused by premature deterioration of buildings and structures, deterioration due to corrosion in the steel caused by exposure to an aggressive environment and accident events such as earthquakes. Consequently, The maintenance, rehabilitation and upgrading of structural members is perhaps one of the most crucial problems in civil engineering applications [1]. In such circumstances, there are two possible solutions: replacement or strengthening. Full structure replacement might have determinate disadvantages such as high cost for material and labor, a stronger environmental impact and inconvenience due to interruption of the function of structure. When possible, it is often better to repair or strengthening.

Basically, the technique involved attaching fiber reinforced polymer (FRP) sheets to the surface of the concrete. The sheets then act compositely with the concrete and help to carry the loads.

Number of articles has been interested to study external strengthening by using CFRP sheets. So, significant amounts of research were conducted on (beams, columns, slabs, bridges and other applications) to provide external reinforcement. While (CFRP) sheets for strengthening concrete is rare in channel applications. Therefore, the applications of CFRP strengthening are reported in this chapter. Such as, Meier moderated the first application in (1991) of the Ibach Bridge in the canton of Lucerne. In addition, several applications (Bridge, beams, tunnels, and culvert) of externally bonded FRP reinforcement of concrete structures developed in Japan from [2] were worked experimentally. The strength of concrete beams bonded with CFRP sheets [3], [4], [5] and [6] and GFRP sheets [7] were studied experimentally. The strength of bridge by CFRP Laminates were reviewed by [8], [9], [10] and [11] and slab bridge by [12].

Different surface roughness due to the strengthening by (CFRP) sheets affects of the hydraulic characteristics of the flow within the channel. Namely, influence mainly on Chezy coefficient of the channel. The Chezy C may depend on the channel shape, size, and roughness and on the Reynolds number [18]. Hence, many previous studies to estimate and calculate the new factor.

Pinaki Prasanna Nayak, (2010) [13] Presented the variation of roughness coefficients for meandering channels with slope, sinuosity and geometry. The loss of energy in terms of Manning's n , Chezy's C , and Darcy-Weisbach coefficient f are evaluated. A simple equation for roughness coefficient based on dimensional analysis is modeled and tested with the recent

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experimental data. The method gives discharge results that are comparable to that of the observed values as well as to other published data.

John E. Gilley et al. (1991) [14] discussed the analysis of surface runoff on upland areas, which requires identification of roughness coefficients. Consequently, a laboratory study was conducted. Varying rates of flow were introduced into a flume in which selected amounts of residue were securely attached. Roughness coefficients were calculated from measurements of discharge rate and flow velocity.

Zarina Md Ali et al. (2011) [15] determined the affects of gravel bed to roughness characteristics in channel. An experimental works were carried out by used flumes (10m x 0.3m x 0.46m) with gravel and smooth bed surface. The roughness coefficient obtained by flume gravel bed surface is bigger than flume with smooth bed surface. Consequently, the objective of this investigation is (1) to investigate the flexural behavior of reinforced concrete channels strengthened with varying locations of CFRP sheets and drawing load-deflection and studied failure mode. (2) To study the effect of CFRP sheets

on the hydraulic principle of the flow, especially on Chezy factor (c) with different discharges.

2 EXPERIMENTAL SETUP:

In this study, the experiments have been conducted in the graduate studies laboratory in the civil engineering department at the Kufa University, Najaf, Iraq. The channels were casted for this experimental work program. The dimensions of all specimens are identical; the channel section is trapezoidal in cross section. So, it is 45cm bottom wide, 60° side slope having depth of 40 cm and the length is 160 cm depending on the best hydraulic section for trapezoidal channel. Reinforcing steel for each specimen of channels is in the form of two layers, each layer consisting of longitudinal and transverse reinforcement with diameter 4 mm @15cm spacing shown in figure(1).

The materials used in this study were conformed to Iraq specification. In the present study, the maximum aggregate size was 10 mm. Mix design details are as given in Table (1).

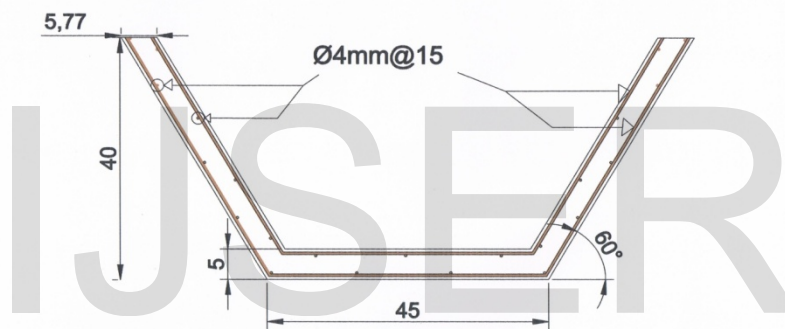


Fig. 1 channel dimensions and location of reinforcing steel

Table. 1 Concrete mix design proportions for channels

Ingredients	Quantity
Total cement (kg/m^3)	420
Fine aggregate (kg/m^3)	710
Coarse aggregate (kg/m^3)	1100
Water (kg/m^3)	159.6
Admixture (l/m^3)	3
Water/cement ratio	0.38

The experimental study consists of casting four reinforced concrete (RC) channels. The strengthening of the channels is done with vary location of CFRP sheets.

Before conduct flexural examination on strengthened channels from inside, linked channels to be flume with (6.4m) length, after providing all that is necessary for this experiment

until finding Chezy coefficient for two cases: (1) Flume Without CFRP sheets, and (2) Flume with CFRP sheets.

3 HYDRAULIC MODELING EXPERIMENT

3.1 EXPERIMENTAL FACILITIES:

- A. **Experimental site.** Experiments are conducted at the Hydraulic Engineering Laboratory of Department of Civil Engineering at kufa University (Iraq) using a tilting trapezoidal flume, with a slope (1/320).
- B. **Reservoir tanks:** Source water from two reservoirs Capacity (2000L) with connection pipes by diameter (3 inch). In addition, an outflow tank, 2 m long, 0.8 m wide and 0.5 m deep.



Photo 1 the tanks inflow

C. **Pumps:** Water is pumped into the flume from pump with maximum capacity is (12L/sec). In addition, the reflux water pull by another pump, it is same quality as the first pump. The pumping system is supplied with a valve to control the discharge.



Photo 2 pump inflow

D. **Screen:** a vertical steel screen at about the middle of the inlet basin For the purpose of calming the flow.



Photo 3 the screen

E. **V-notch weir:** the weir was used in experimental work is partially contracted standard 90-degree V-notch weir. The crest of the weir consists of a thin plate beveled 45 degrees

from the vertical to produce an edge no thicker than (2mm) and thickness of plate (1cm). In addition, it used from plywood material. It is an accurate flow measuring device particularly suited for small flows and use in calibration between discharge from weir and discharge from volumetric method. The cone equation is commonly used for 90degree V-notch weirs. This equation is reliable for small, fully contracted weirs generally encountered in measuring water for irrigation [16], [17] and [18] .

$$Q= 1.34H^{2.48} \quad (1)$$

Q = discharge over weir in m³/s
 H = head on the weir in m.



Photo 4 V-notch weir in experimental work

f. **Slope Adjusting Automatic Device:** two devices used in experimental work to adjust the bed slope. One of those put in the beginning and the other in mid the flume. After that, we realize the desired slope by bed level device.



Photo 5 Slope Adjusting Automatic Device

G. **Steel base for carry the flume.**

3.2 EXPERIMENTAL PROCEDURE

Water is supplied to the experimental setup by a recirculation system of water supply. Pump capacity (3 inch) is used to pump water from processing tanks to the flume by pipes capacity (3 inch). Water is led to a stilling screen located at the upstream of the channel. A series of baffle Walls between the stilling screen and the flume are kept to reduce turbulence of the incoming water. At the end of the experimental channel, water is allowed to flow through a V-notch weir and is collected outflow tank from where it is allowed to flow back to the processing tanks. Water is pumped back, Thus setting a complete recirculating system of water supply for the experimental channel. The weir is located at (70cm) from downstream, and it helps to measured the discharge and work calibration. The discharges are determined by volumetric method, and then depend on specific five discharges. Experiment is performed on three cases:

1. Concrete channel
2. Concrete channel strengthened by five tapes from (CFRP) sheets with width (5cm) and long (122cm) with transverse direction.
3. Concrete channel strengthened by fifteen tapes from (CFRP) sheets with width (5cm) and long (122cm) with transverse direction.

Each case conducted in the experiment on five discharge (6.5, 8, 9.5, 11 and 12) l/sec. it is calculated from each experiment depth of water, then enter in chezy equation to find chezy roughness coefficient.

$$Q = C \times R^{1/2} \times S_0^{1/2} \times A \quad (2)$$



Photo 6 flume with 5 tapes from CFRP sheets



Photo 7 flume with 15 tapes from CFRP sheets

4 STRUCTURAL EXPERIMENTS

In order to investigate the capability of CFRP to strengthen of concrete channels; four specimens made of concrete were prepared. For the concrete channels, one remained without strengthening and was kept as a control specimen (c1), while the rest were strengthening. Table (2) shows the nomenclature and location of strengthening of each group.

Table 2 Nomination of specimens showing the strengthening condition

Channel remark	Position of CFRP sheet
C1	No strengthen
C2	CFRP is represented in the form of 3 strips, 5 cm in width within the channels in the transverse direction
C3	CFRP is represented in the form of 5 strips, 5 cm in width within the channels in the transverse direction
C4	CFRP is represented in the form of 5 strips, 5 cm in width within the channels in the transverse direction and one strip in both corner in longitudinal direction with 30cm width and 160cm long

The channels were simply supported at each end. In order to simulate the real boundary condition of the actual structure. Namely, both horizontal and vertical forces from effect the water. Consequently, the most commonly used load arrangement for testing of channels will consist two patch loading arrangement was done affect on the center the wings of the channel. For all cases the dial gauge was placed just below the center of the channel to measure deflections.

4.1 TEST METHOD

Flexure test was conducted to compare the behavior of the channels with and without CFRP strengthening. Before testing the channel must checked dimension and location the support and dial gauge and a detailed visual inspection made with all information carefully recorded. After setting and reading the gauge, the load was increased incrementally. The loads and deflections recorded at each stage. Loads will then normally be increased again in similar increments up to failure. Similarly, cracking and deflections observations must be suspended as failure approaches unless special safety precautions are taken. If it is essential that precise deflection reading are taken up to collapse. Cracking was checked visually and a load/deflection plot was prepared.

5.1 ROUGHNESS COEFFICIENTS IN OPEN CHANNEL

The experimental results for Chezy roughness coefficient (C) with discharge for flume investigated are plotted in figure (3) for slope (0.003125). Chezy coefficient is found to increase with increase of discharge due to higher depth of flow. So, Chezy coefficient is found with put CFRP sheets by five stripes for the purpose of strengthening the flume, its increase for the same discharge for the first case (without CFRP sheets). In addition, more Chezy coefficient is with put (15) stripes from CFRP sheets. The reason for this probably to smooth surface for CFRP sheets which is considered one of the advantages of CFP sheets. So CFRP also beneficial in economic terms because it gives increased in discharge.

5 RESULTS AND DISCUSSION

Table 3 first case concrete channel without CFRP sheets

S (m/m)	Q (m ³ /s)	y _{up} (cm)	y _{down} (cm)	y _{avg} (cm)	A (m ²)	P (m)	R (m)	C
0.003125	0.0065	4.5	3.5	4	0.016615	0.48466	0.034282	37.79
	0.008	4.9	3.8	4.35	0.018157	0.4927415	0.036849	41.07
	0.0095	5.2	4.1	4.65	0.01949	0.4996685	0.039005	44.15
	0.011	5.5	4.4	4.95	0.020833	0.5065955	0.041123	46.65
	0.012	5.9	4.5	5.2	0.02196	0.512368	0.042859	47.37

Table 4 second case concrete channel with 5 stripes of CFRP sheets

S (m/m)	Q (m ³ /s)	y _{up} (cm)	y _{down} (cm)	y _{avg} (cm)	A (m ²)	P (m)	R (m)	C
0.003125	0.0065	4.5	3.4	3.95	0.016396	0.4835055	0.033911	38.51
	0.008	4.9	3.6	4.25	0.017715	0.4904325	0.036121	42.5
	0.0095	5.2	3.8	4.5	0.018822	0.496205	0.037932	46.35
	0.011	5.6	4.1	4.85	0.020384	0.5042865	0.040421	48.02
	0.012	5.9	4.2	5.05	0.021283	0.5089045	0.041821	49.32

Table 5 third case concrete channel with 15 stripes of CFRP sheets

S (m/m)	Q (m ³ /s)	y _{up} (cm)	y _{down} (cm)	y _{avg} (cm)	A (m ²)	P (m)	R (m)	C
0.003125	0.0065	4.5	3	3.75	0.015523	0.4788875	0.032414	41.6
	0.008	4.9	3.2	4.05	0.016835	0.4858145	0.034652	45.68
	0.0095	5.2	3.3	4.25	0.017715	0.4904325	0.036121	50.47
	0.011	5.6	3.5	4.55	0.019044	0.4973595	0.038291	52.88
	0.012	5.9	3.6	4.75	0.019936	0.5019775	0.039715	54.03

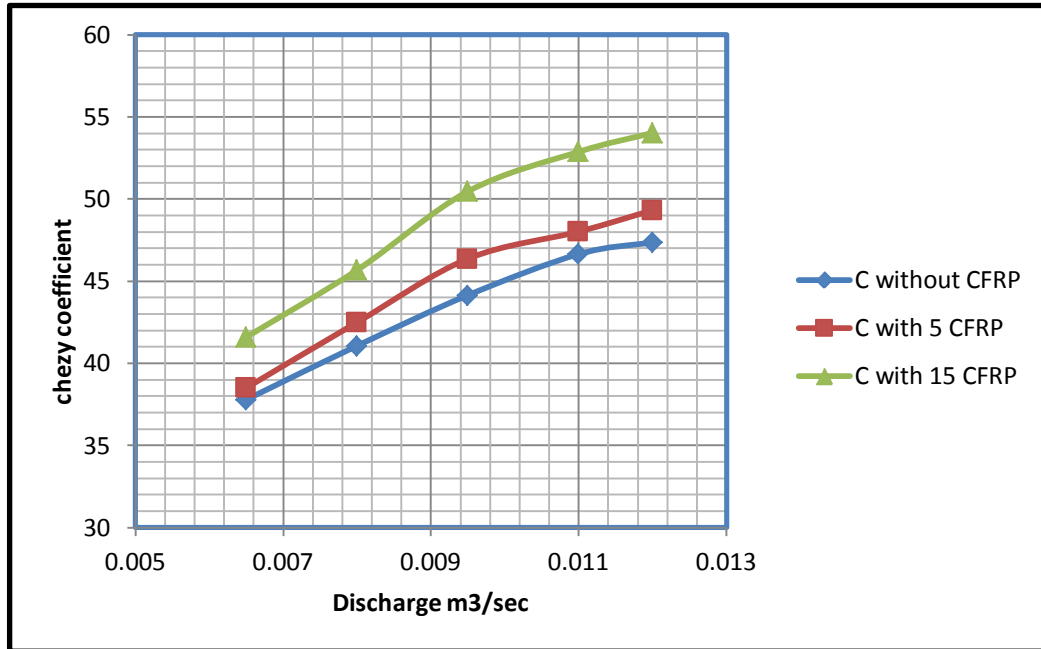


Fig. 2 Chezy coefficient vs. discharge for slope=0.003125

5.2 FLEXURAL TEST RESULT

In the current study, in all the channels, the failure occurs starting with flexure cracks at corners followed by interfacial debonding failure of the CFRP system. The CFRP strengthened channels and the control channel were tested to find out their ultimate load carrying capacity. It was found, Failure in the control channel (C1) was typical that of under-reinforced

RC flexural members, which is characterized by yielding of steel rebars followed by concrete crushing. In channels (C2), (C3) and (C4) failure was caused by crushing of concrete followed by debonding of the CFRP from the concrete.



Photo 8 Final Failure in control channel C1



Photo 9 Final Failure in control channel C3

Table 6 summarizes the experimental values for initial crack and ultimate capacity obtained in each test.

Channel designation	Load at Initial crack (KN)	Ultimate load (KN)
C1	11.5	16
C2	13	18
C3	17.5	32.5
C4	24	38

From the load and deflection of data of channels C1, C2, C3 and C4, load vs deflection curve is plotted for all the four channels. From this load vs deflection curve, it is clear that channel C1 lower ultimate load carrying capacity compared to

channels C2, C3 and C4. Channel C1 had also undergone higher deflection compared to channels C2, C3 and C4 at the same load. Channel C2 had higher ultimate load carrying capacity compared to the controlled channel C1 but lower than channels C3 and C4. Channel C3 had higher ultimate load carrying capacity compared to the channels C1 and C2 but lower than channels C4. Channel C4 had higher ultimate load carrying capacity compared to the channels C1, C2 and C3. The deflection undergone by channel C4 is highest, channel C3 had undergone higher deflection than channel C2, and channel C2 had undergone higher deflection than channel C1. The figure (7) showed load vs deflection curve for channels C1, C2, C3 and C4 for dial gauge at mid-span.

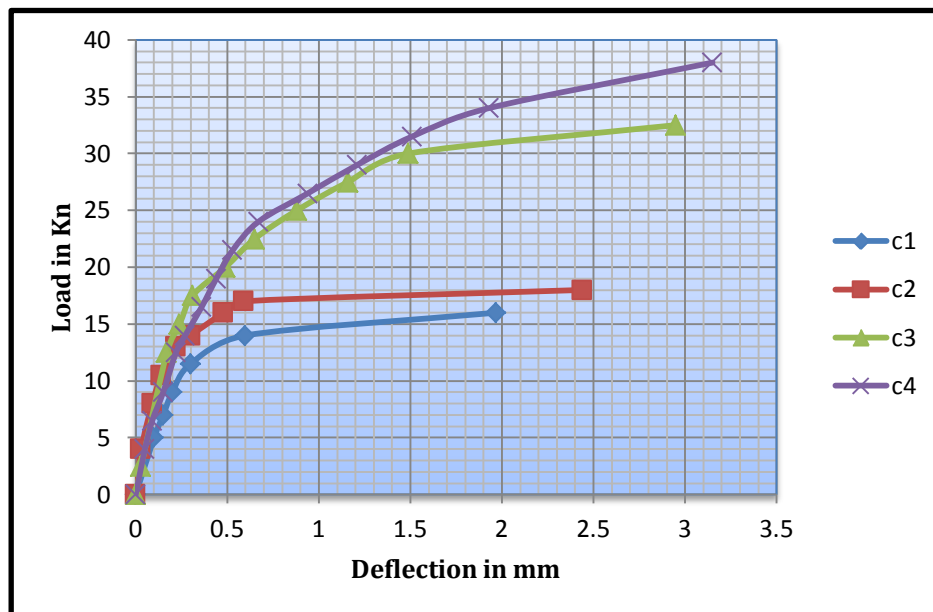


Fig. 3 load vs deflection curve for channels C1, C2, C3 and C4

6 CONCLUSIONS

The experimental set-up was designed to evaluate strengthening of concrete channel by externally bonded CFRP reinforcement. In addition, this study presents the effect of CFRP sheets on the Chezy roughness coefficient in an open channel. Consequently, two tests have conducted with four specimens of channel. The hydraulic test results indicate that Chezy coefficient (c) is increase with increasing ratio of CFRP sheets to concrete. Namely, At the slope (0.003125), the Chezy coefficient is about (4%) increases in the maximum discharge when the CFRP sheets is 5 stripes in channel and about (12.3%) increases when the CFRP sheets are 15 stripes in channel. In addition, the flexural test indicate that The externally bonded CFRP sheets have increased the stiffness and maximum load of the channels and The cracks and the deflections have decreased for strengthened channels. We suggest that further research could focus on the vegetated effects of CFRP sheets and usage of the extended finite element method to represent the cracks in the concrete.

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