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STRUCTURAL BEHAVIOR OF COMPOSITE SLABS SUBJECTED TO IMPACT LOADING

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Abstract

This paper presents the experimental results of composite slabs under static and impact loading. Total of six specimens classified one specimen test under static loading and the remaining five were tests under impact dynamic loading with different parameters as type of connections and degree of interaction of composite slab. Low - velocity impact test was adopted by select the falling mass (4 kg) made from steel material and formed as ball shape without nose. The ball dropped freely from height of (2.4 m) and strikes the top of composite slab. The designed dimensions of specimens is (500×500×60 mm) as reinforced concrete slab that reinforced by mesh of (RBC) and the steel plate is (3 mm) in thickness. Deflection due to first crack is recorded, number of blows caused first crack and failure were counted. The test results showed that the welded stud connectors gives high strength capacity and resistance under static and impact dynamic loadings than other than type of connections, also, full interaction as degree of interaction is better than others.

Keywords: Composite slab, Impact loading, Experimental test, Slip, Strength capacity, Resistance

Introduction

Many researchers was studied and investigated the structural composite structural elements that subjected to static loading, but a few concentrated on composite slab behavior and resistance in case of using epoxy to connect the two different materials as full epoxy between reinforced concrete slab and steel plate or between glued stud connectors and steel plate under dynamic loading. Impact analysis is a branch of dynamic applied loading, below some researchers that adopted and looked out on the behavior of structural elements under the effect of impact loading. M. Zineddina and T. Krauthammer (1) 2007, investigated the dynamic behavior of reinforced concrete slab that subjected to impact loading. The slab reinforcements and amount of applied loading was investigated. The specimens were divided into three groups according to slab geometry and amounts of reinforcements. The mass dropped from "0.152, 0.305 and 0.610 m". The data recorded by tests result as strain, deflections, and load-time curve indicated that the response of a slab is affected by the amount of steel reinforcement, drop height and the reinforcement quantities affected the slab failure modes. Selcuk Saatci (2) 2007, investigated experimentally and theoretically approaches to study the behavior of reinforced concrete beams under impact loading. The eight specimens beams was tested under free mass failing at mid – span and checked the shear resistance of beams. All beams have same geometry and main reinforcement but the variable was the shear reinforcement. The beams were failed under shear and there was diagonal cracks performed under the effect of impact loading. Faham Tahmasebinia and Alexander Remennikov (3) 2008, simulated reinforced concrete slab that subjected to impact loading. The results examined with the experimental works and showed that closed and declared that the numerical methods as finite elements approached gives more details and cost effective than experimental tests. Mohammed Tarrad (4) 2009, investigated the Ferro-cement slabs subjected to impact loading and modified by polymer. The parameters that considered were of wire mesh layers, polymer and mass failing height. The specimens tested under low and high velocity using mass "1.3 kg" and dropped from "0.83, 1.2 and 2.5 m" and strike reinforced concrete slab has dimensions "500x500x50 mm". The test results indicated that the number of strike required producing first crack and failure, increased with increase of polymer content and wire mesh layers. For high velocity impact test, the area of scabbing and area of spalling decreased with the increase of polymer content and wire mesh layers compared with reference mixes. The mechanical properties of concrete increased with increase the polymer content. K. T. Tan et al. (5) 2011, studied the impact that cause damaged of laminated composite layers that reinforced through-thickness stitching. The first part of tests included the exploration of damaged area using ultrasonic analysis and showed that when the layer thickness thin the damaged area and cracks propagations become more than when used thicker layers. The second part that investigated the response of impact damage that relay on the numbers of layer. The mechanism of impact damaged was investigated using X ray to reveal the damaged at the surface and internal cracks. Sandeep Agrawal et al. (6) 2014, reviewed the impact damages of reinforced concrete composite materials. The variables that considered were shape of dropped mass, impact mass, impact velocity and environments at tested time. Low velocity was considered in the study and the cracks propagation observed and the tests result showed that the polymer susceptible to the impact loading. Most damaged occurred at the surface due to mass dropping at the top even for little mass and height. Andreas Andersson (7) 2014, investigated the capacity of slab that subjected to static and dynamic impact loading. Total of eighteen specimens was tested with size (1750x1750x120 mm). Impact test was done by failing (600 kg) mass from height that ranged between one and two meters. All slabs was failed under flexural failure and some slabs fallout of concrete during impact. A. Saadun et al. (8) 2016, looked out by tested a lot of cylinder specimens that contain percentages of polypropylene fiber under the effect of impact loading. Three mixers for each sample specimen was casted and then tested by applied impact load. Results of compressive strength were increased as compared with the control specimen.

In present paper, the parameters that adopts are type of connections and degree of connections of composite slab, also the type of loading as static and impact dynamic loading.

2. Experimental program

The control composite slab was designed according to the full interaction (100%) theory and from this design some specimens were reduced to 50% and 0% interaction to investigate the effects of partial and no interaction on the behavior and strength of composite slab in case of static and impact dynamic loading.

Static tests were done first to check the adequacy and strength capacity of composite slab. The impact dynamic tests done by dropped freely steel ball (4 kg) to the top of composite slabs from height (2.4 m). Composite slab classified also by the type of connections, one group the stud connectors connected to the steel plate by welding, second type, the connectors glued at the top of steel plate by epoxy, third type, the slab connected to the steel plate by epoxy only (no stud connectors), finally, there was no connections between concrete slab and steel plate (slab casted directly above steel plate), see Table (1).

2.1 Static tests

One specimen was tested with degree of interaction (50%). The test results for loading capacity, deflection and slip was recorded in Table (2) and plotted in Figures (1) and (2) for ultimate loading capacity and maximum deflection and slip, respectively. Specimen setup and rest at the machine test shown in Plate (1) before and after test. Dial gauges were fixed at the central bottom point of slab to measure central deflection and at side to measure the cumulative slip. Failure mode for all specimens is flexural as shown in Plate (2).

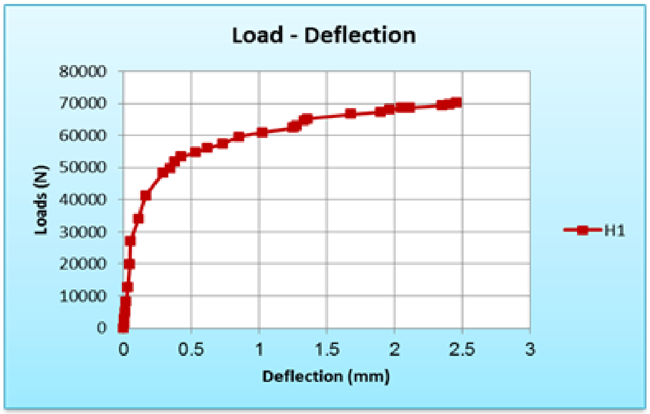

Figure (1): Load – deflection – Static test

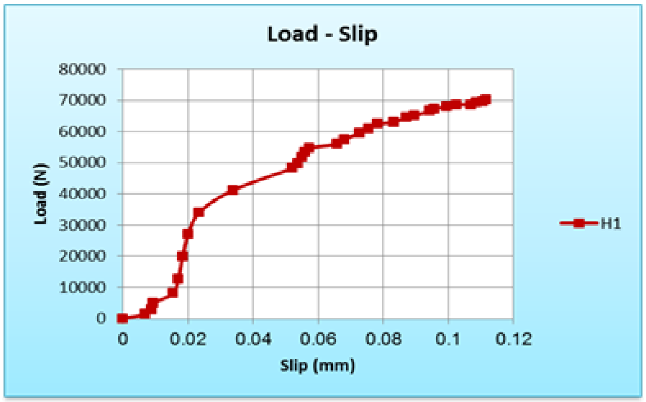

Figure (2): Load – slip – Static test

Plate (1): Specimen setup – before test

Plate (2): Specimen – after test

2.2 Impact test

Five specimens were tested under impact loading by mass (4 kg) dropped freely from (2.4 m) height See Figure (3) [9]. Two dial gauges were sated under the steel plate to measure the central deflection, the frame used as shown in Plate (3) and failure of composite specimen failure (concrete failure) as shown in Plate (4). Number of blows cause first crack under the effect of degree of interaction as shown in the Figure (4), Number of blows cause failure under the effect of degree of interaction as shown in the Figure (5) and the central bottom deflection behavior for first blow under the effect of degree of interaction is shown in Figure (6).

Table (1): Specimen details

Mark	%Degree of interaction	Type of connection	Loading type
H1	50	Welding	Static
H2	50	Glued studs by epoxy	Impact
H3	No studs	Glued plate by epoxy without stud	Impact
H4	0	Welding	Impact
H5	50	Welding	Impact
H6	100	Welding	Impact

Table (2): Test results for static loading

Mark	First crack loading (kN)	Ultimate loading (kN)	Deflection at first crack loading (mm)	Slip at first crack loading (mm)	Maximum deflection (mm)	Maximum slip (mm)
H1	24.86	70.07	0.046	0.019	2.463	0.112

Table (3): Test results for impact loading

Mark	Number of blows for first crack	Number of blows up to failure	Deflection at first blow (mm)
H2	7	85	0.125
H3	5	73	0.131
H4	3	62	0.133
H5	10	127	0.123
H6	15	150	0.118

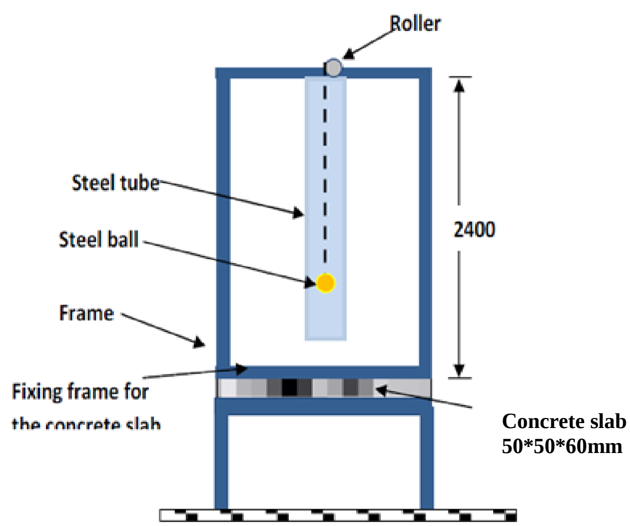

Fig. (3): simplified sketch for the low velocity impact test setup [9]

Plate (3): Frame test for impact loading

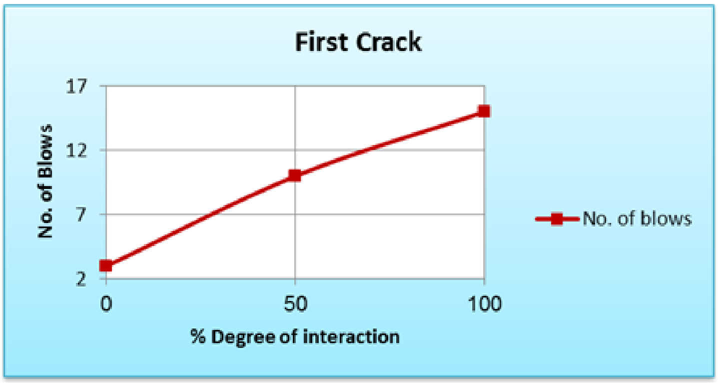

Figure (4): Number of blows that cause first crack under the effect of degree of interaction

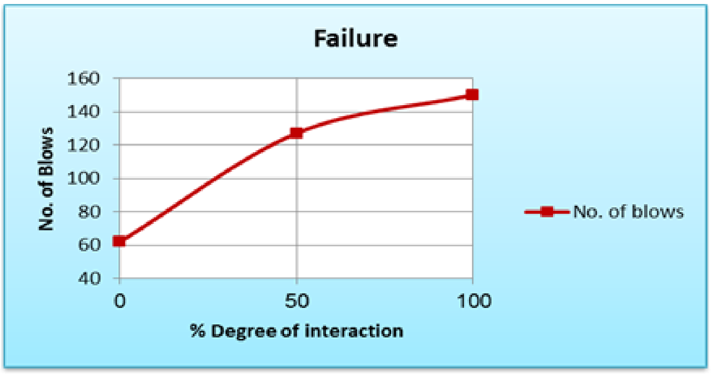

Figure (5): Number of blows that cause failure under the effect of degree of interaction

Plate (4): Failure of specimen under impact loading

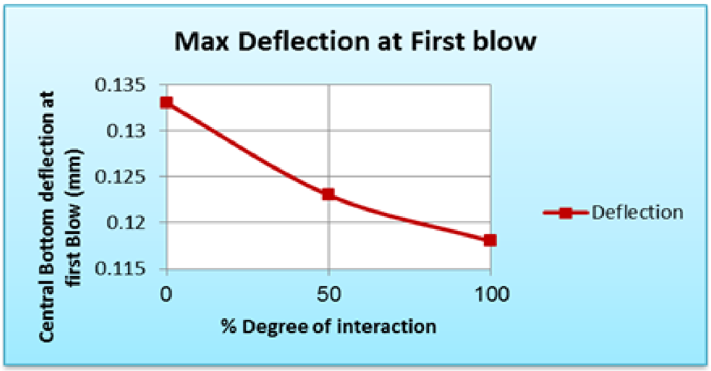

Figure (6): Central bottom deflection for first blow under the effect of degree of interaction

3.Discussions of test results

According to the test results with parameters that adopted and looked out, followings are the points that were observed and recorded from tests and the full behavior of parameters:

3.1 Static load test

Composite slabs were tested according to the design capacity that calculated before tests. The load – deflection and load – slip curves that mentioned above described the full behavior of composite slabs under static loading. The maximum deflection for composite slab limit is (span/250), so the result deflection around this value.

3.2 Impact loading test

In impact dynamic tests the three important things that make discussions are number of blows to cause first crack, number of blows up to failure and the deflection in case of first blow.

In case of full interaction (100%), the number of blows requires to reach first crack and to reach to the failure (collapse) of specimen will increase when compares with (0 and 50%) interaction, the test results lists in Table (3). The increase percentages of composite slab (100% interaction) with the (0 and 50%) interaction as number of blows requires to reach first crack are (+400%), (+50%) respectively. And (+142%), (+18%) as number of blows requires to reach the failure. This is because the two materials works as unity so that modulus of elasticity and moment of inertia become high to resists the impact loading. In case of (0%) interaction that is mean each material worked separately and there is no composite action so that the resistance strength becomes less when compared with full or (50%) composite action. Deflection produce by first blow for full composite is less than other degree of interaction, the test results lists in Table (3). The percentages decreases of composite slabs in case of (100% interaction) with the (0 and 50%) interaction are (-11%), (-4%) respectively.

Based on the type of connections as welded stud, glued stud by epoxy, glued plate by epoxy without stud and casted slab directly above steel plate, the number of blows to cause first crack, failure and deflection were affected. Resistance capacity increased when the stud connectors welded to the steel plate because of the composite slab action become high, tight and working as single especially in case of full interaction. The number of blows requires the first crack appear and the blows at failure stage are less than in case of connect the stud connectors by epoxy when using welding stud connectors. The decrease percentages of composite slab (50% interaction) as number of blows requires to reach first crack, number of blows requires to reach the failure and increase in percentage of deflection are (-30%) , (-33%) and (+2%) respectively**,** because of the strength resistance and capacity of welding greater than epoxy and the epoxy more ductile and gives more movements there were slip make reducible in resistance strength and the welded stud connectors become stiffer to resists the impact loading.
In case of no stud connectors only epoxy between concrete slab and steel plate (H3), The numbers of blows in this case are less

than the (composite with 100% interaction) with decreases percentage (-67%) and (-51%) for first crack , failure respectively and increase in percentage of deflection by (+11%) . The strength capacity reduced because of presence of slip and worked as partial interaction**.**

4. Conclusions

According to the tests result from experimental, followings are the most important points that concluded and summarized below:

1. Composite slab with full interaction give resistance strength capacity more than other degree of interactions in case of impact loading.
2. Composite slab with full interaction give deflection less than other degree of interactions under the effect of impact loading.
3. Composite slab with welded stud connectors give resistance strength capacity more than other type of connections in case of impact loading.
4. Composite slab with welded stud connectors give deflection less than other type of connections under impact loading.
5. Connection type by welded stud connectors give better results as compared with epoxy under impact loading.
6. The numbers of blows required for first crack are more than in case of full interaction than (0 and 50%) interaction. The percentage increases are (+400%) and (+50%) respectively.
7. The number of blows required to fail the specimen for full interaction are more than (0 and 50%) interaction. The percentage increases are (+142%) and (+18%) respectively.
8. The deflection for first blow for full interaction is less than (0 and 50%) interaction. The percentage decrease are (-11%) and (-4%) respectively.
9. The numbers of blows are less to reach the specimen up to first crack in case of studs glued by epoxy than welded studs. The percentage decreases is (-30%).
10. The numbers of blows are less to reach the specimen up to failure in case of studs glued by epoxy than welded studs. The percentage decreases is (-33%).
11. The deflection at first blow in case of studs glued by epoxy is more than welded studs. The percentage increase is (+2%).
12. Composite slab when the concrete slab glued with steel plate by epoxy has deflection is greater than composite slab in case of full interaction (100%) by (+11%). Also, the number of blows up to first crack and failure are less by (-67%) and (-51%) respectively.

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التصرف الانشائي للبلاطات المركبة تحت تأثير حمل الصدم

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الخلاصة

في هذا البحث تم دراسة التصرف الآنشائي للبلاطات المركبة والمعرضة الى حمل الصدمة. تم فحص ستة نماذج من البلاطات المركبة الاول بتسليط حمل ساكن والخمسة المتبقية تم فحصها تحت تاثير حمل الصدمة والتي تم الأخذ بنظر الاعتبار عدة متغيرات من حيث (نوع الربط ودرجة الآرتباط للبلاطات المركبة). الكتلة المستخدمة للصدم (4 kg) وتم اسقاطها من على ارتفاع ثابت (2.4 m). الأبعاد التي اعتمادها للبلاطات المركبة هي (500mm x500x60) للبلاطة الخرسانية التي تم تسليحها بحديد (BRC) والصفيحة الحديدية من الآسفل بسمك (3 mm). تم احتساب عدد الضربات التي ادت الى ظهور الشق الاول وايضا" عدد الضربات التي أدت الى الفشل بالآضافة الى قياس مقدار الهطول بالضربة الآولى. وقد بينت نتائج الفحوصات العملية ان الروابط القصيه (Stud shear connectors)عندما تلحم مع الصفيحة الحديدية تعطى مقاومة أعلى من النوع الاخر للربط (الأيبوكسي) وان درجة الارتباط (Degree of interaction) بين عناصر البلاطة المركبة لها تأثير على مقاومة البلاطة تحت تأثير حمل الصدم.

الكلمات الدالة:البلاطة المركبة ,حمل الصدم,فحوصات تجريبية,انزلاق,المقاومة.