Blast Resistant Structures-A Review

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Abstract—Due to the rising threat of terrorism, protecting critical civil infrastructure such as embassies, government buildings, and airports against bomb attacks has become a critical issue. Therefore, there is a need for the development of technologies that can protect these structures against blast loads. Categories of available protection technologies currently include exterior steel cladding and the addition of concrete walls, and sprayed-on polymer and metallic foam cladding. Further, extremists are using newer chemicals and technological advancements that have increased blast event magnitudes. Therefore, in addition to strategically important and heritage structures, even important commercial buildings and complexes are required to be designed for an adequate level of blast resistance. On the other hand, blast-resistant design of structures is treated as a specialized area to which, commonly, structural engineers are not exposed comprehensively, and most of the knowledge about blast-resistant design of structures remains limited to military setups. Hence, it is intended herein to present various strategies for blast response mitigation and structural design of such protective structures. This report is meant for discussion of studies on blast resistant structure and blast loading.

Key words: Blast Resistant, Blast Loading

I. INTRODUCTION

In recent years, because of increased fanatic activities, civil structures are exposed to threats from blast-induced impulsive loads. Several such incidents have taken place around the world, causing serious threat to life and property. The awareness regarding the need for the protection of structures to blast loads is not a new problem. In fact, it was stated during the 1987 Structures Congress that protection of structures against terrorist attacks was already at that time considered to be an existing problem. Since blast protection of structures is never an absolute concept and there is always an associated high cost with any increased level of damage protection, proper assessment tools must be employed to determine within a reasonable degree of accuracy the level of vulnerability of new as well as existing structures.

As important, design and construction techniques must be also developed and improved with the main goal of increasing the blast resistance capacity of structures. Further, extremists are using newer chemicals and technological advancements that have increased blast event magnitudes. Therefore, in addition to strategically important and heritage structures, even important commercial buildings and complexes are required to be designed for an adequate level of blast resistance. On the other hand, blast-resistant design of structures is treated as a specialized area to which, commonly, structural engineers are not exposed comprehensively, and most of the knowledge about blast-resistant design of structures remains limited to military setups. Hence, it is intended herein to present various strategies for blast response mitigation and structural design of such protective structures.

Based on this agreed threat level, the acceptable damage to the structure is decided and designed accordingly. However, it is to be noted that no structure can be designed to be fully protected against all threat levels, which evolve in time, and a strategy needs to be adopted that can be altered or improved per new requirements, even later on, without much intervention to the parent structure. Hence, herein various strategies for blast mitigation are reviewed that can be adopted right from the stage of structural design. Blast-resistant design necessitates use of material and geometric nonlinearities to exploit energy absorption mechanisms.

A. *Blast Loading*

The purpose herein is to present a quick overview of blast-induced loading and provide the references used for its computation. The first step in the blast-resistant design of structures is to know how to define the blast loading. The structures may be subjected to blast loading, which comprises blast pressure, ground shock, and fragment impact, particularly in the near-range region; whereas, in the far-field region, structures are subjected to only blast pressure. An explosion is defined as a large-scale, rapid and sudden release of energy. Explosions can be categorized on the basis of their nature as physical, nuclear or chemical events. In physical explosions, energy may be released from the catastrophic failure of a cylinder of compressed gas, volcanic eruptions or even mixing of two liquids at different temperatures. In a nuclear explosion, energy is released from the formation of different atomic nuclei by the redistribution of the protons and neutrons within the interacting nuclei, whereas the rapid oxidation of fuel elements (carbon and hydrogen atoms) is the main source of energy in the case of chemical explosions. The detonation of a condensed high explosive generates hot gases under pressure up to 300 kilo bar and a temperature of about 3000-4000C°.

Explosive materials can be classified according to their physical state as solids, liquids or gases. Solid explosives are mainly high explosives for which blast effects are best known. They can also be classified on the basis of their sensitivity to ignition as secondary or primary explosive. The latter is one that can be easily detonated by simple ignition from a spark, flame or impact. Materials such as mercury fulminate and lead aside are primary explosives. Secondary explosives when detonated create blast (shock) waves which can result in widespread damage to the surroundings.

II. LITERATURE REVIEW

Blast Testing of Aluminum Foam-Protected Reinforced Concrete Slabs Chengqing Wu et al, studied on applying aluminum foam as a sacrificial protection layer on the bearing faces of protected structures can mitigate blast effects on the resistant capacities of structures against impact or blast loading. In this paper the authors have performed testing on two types of aluminum foam

specimens and obtained the primary parameters for the mechanical properties of aluminum foam specimens. The authors have tested a total of five foam-protected slabs and one control RC slab in the blast test program. Results of the blast testing indicate that foam layers used to protect RC slabs in the test program were effective in mitigating blast effect on RC slabs. The blast test data and mechanical properties of foams could be used to validate a numerical model that considers interaction between foam layers, blast loading, and structural members.

Blast–resistant characteristics of ultra-high strength concrete and reactive powder concrete Na-Hyun Yi et al, investigated on the blast-resistant capacities of ultra-high strength concrete (UHSC) and reactive powder concrete (RPC). The authors have experimentally evaluated to determine the possibility of using UHSC and RPC in concrete structures susceptible to terrorist attacks or accidental impacts. The authors have carried out slump flow, compressive strength, split tensile strength, elastic modulus, and flexure strength tests. In addition, ANFO blast tests was performed on reinforced UHSC and RPC panels. Incidental and reflected pressures, as well as maximum and residual displacements and the strains of rebar and concrete was measured. Blast damage and failure modes of reinforced panel specimens was recorded. The authors have concluded that UHSC and RPC have outstanding material properties and blast-resistant capacities.

Experimental Investigation of Seismically Resistant Bridge Piers under Blast Loading Shuichi Fujikura and Michel Bruneau, studied on blast resistance of bridge piers that are designed in accordance with specifications to ensure ductile seismic performance. The authors have conducted blast testing on ¼ scale ductile RC columns, and non-ductile RC columns retrofitted with steel jacketing. The authors have reported that the seismically designed RC and steel jacketed RC columns did not exhibit a ductile behavior under blast loading and failed in shear at their base rather than flexural yielding. A moment-direct shear interaction model was proposed to account for the reduction of direct shear resistance on cross sections when large moments are simultaneously applied. This made it possible to match and explain the experimentally obtained behavior when direct shear strength was compared with the shear demand obtained from plastic analysis.

Experimental Performance of Concrete Columns with Composite Jackets under Blast Loading Tonatiuh Rodriguez-Nikl et al, studied on performance of concrete columns with composite jackets under blast loading. The authors have tested nine rectangular RC specimens with and without FRP jackets under quasi-static blast like loading. One of the jackets had fibers orientated along the transverse and longitudinal directions; the rest were transverse only. The authors have reported that the specimens with FRP jackets was observed to form ductile three-hinge mechanisms whereas those without jackets failed suddenly in shear. The experimental results were used to assess the UCSD shear model and standard guidance for resistance functions contained in UFC. They identified Limitations in both approaches. They concluded that the UCSD shear model had performed well.

Blast Resistance capacity of Reinforced Concrete Slabs Pedro F. Silva and Binggeng Lu, investigated the basis of a procedure to estimate the explosive charge weight and stand-off distance to impose certain levels of damage on reinforced concrete (RC) structures. The authors have conducted a series of experiments on RC slabs and its material properties. Based on the experimental results they reported that the tested slabs have demonstrated that the achieved displacement ductility levels, damage levels, and residual cracks widths matched the anticipated values reasonably well. From this research they concluded that the charges weight and stand-off distances to generate a given damage level can be effectively estimated by the DBD method. Certainly results also show that their conclusion only applies when punching shear failure is not the governing failure mode.

Experimental and numerical analyses of long carbon fiber reinforced concrete panels exposed to blast loading Zahra S. Tabatabaei et al, reported on experimental and numerical analyses of long carbon fiber reinforced concrete panels (LCFRC) exposed to blast loading. The authors have conducted a series of tests to compare the blast resistance of panels constructed with conventional reinforced concrete (RC) and long carbon fiber-reinforced concrete (LCFRC). A finite element model was created in LS-DYNA to replicate both RC panel and LCFRC panel to observe whether or not the models could predict the observed damage. The authors have reported that the LCFRC panels exhibited less material loss and less surface damage than the RC panels. In addition of LCFRC panels significantly increased the concretes blast resistance and significantly reduced the degree of cracking associated with the concrete panels.

Improving the blast resistance capacity of RC slabs with innovative composite materials Pedro F. silva and Binggeng Lu, studied the feasibility of using innovative composite materials to improve the blast resistance capacity of one-way reinforced concrete slabs. In order to achieve this objective, they tested five slabs under real blast loads. One of the slabs was used as the control unit to establish a baseline for comparison of other four slabs. These four slabs strengthened with carbon fiber and steel fiber reinforced polymers, comprising of two slabs retrofitted on a single side and two slabs retrofitted on both sides. The authors have reported that there was no significant increase in blast resistance when the slabs are retrofitted on a single side; slabs retrofitted on both sides displayed a significant increase in blast resistance. From this research they had also concluded that the charges weight and stand-off distances to generate a given damage level can be effectively estimated by the DBD method.

Blast resistant modular buildings for the petroleum and chemical processing industries Ben F. Harrison, studied on blast resistant portable buildings to protect personnel temporarily assigned duties within explosively hazardous areas. In order to achieve to proper level of protection and building performance several technical siting issues must be considered. These requirements include sliding and overturning during blast response, conventional loading requirements. The author have reported that the blast resistant buildings must be designed and sited such that the appropriate level of protection is provided to workers in hazardous areas. The author have also concluded about sitting issues and selection of the appropriate performance

criteria for blast resistant temporary buildings can greatly reduce the risk to employees in temporary buildings.

Behavior of Ultrahigh-strength Prestressed Concrete Panels Subjected to Blast Loading Tuan ngo et al, investigated on blast-resistance of concrete panels made of ultrahigh-strength concrete (UHSC) material. A special concrete supporting frame was designed for testing concrete panels against blast loading. The authors have tested four 2m x 1m panels with various thickness and reinforcement details under a 6 t TNT equivalent explosion at standoff distance of 30 and 40 m. Data collected from each specimen included blast pressures and deflections of panels. From the test results the authors had reported that the 100-mm-thick UHSC panels performed extremely well surviving the blast with minor cracks. The 75-mm-thick UHSC panel suffered moderate damage while the 100-mm-thick normal strength concrete (NSC) panel was breached. The authors have concluded that the results were used to analyze concrete structure subjected to blast loading.

Experimental study on hybrid CFRP-PU strengthening effect on RC panels under blast loading Ju-Hyung Ha et al, studied on hybrid carbon fiber reinforced polymer (CFRP) – polyuria (PU) strengthening effect on RC panels under blast loading. The combination of CFRP and PU can result in a retrofit composite with enhanced stiffness and ductility properties. The authors have tested nine 1000 x 1000 x 150 mm RC panel specimens retrofitted with either CFRP, PU, or hybrid composite sheets under blast loading. The authors have generated the blast by detonating a 15.88 kg ANFO explosive charge at 1.5 m standoff distance. The authors have measured the data of free field incident and reflected blast pressures, steel and concrete strains from the test. Also the failure mode and crack patterns were evaluated to determine the failure characteristics of the panel. The authors have concluded that the hybrid composite has better blast capacity than other ordinary retrofit FRPs.

Experimental and numerical study of foam filled corrugated core steel sandwich structures subjected to blast loading Murat yazici et al, have studied the influence of foam infill on the blast resistivity of corrugated steel core sandwich panels was investigated experimentally using a shock tube facility and high speed photography and numerically through Finite Element Methods (FEM). After verifying the finite element model, numerical studies were conducted to investigate the effect of face sheet thickness (1, 3 and 5 mm), corrugated sheet thickness (0.2 mm, 0.6 mm and 1 mm), on blast performance. The authors have reported that the greatest impact on blast performance came from the addition of foam infill, which reduced both the back-face deflections and front-face deflections by more than 50% at 3ms after blast loading at a weight expense of only 2.3%. however, increase face sheet thickness and corrugated sheet thickness decreased the benefit obtained from foam filling in the sandwich structure.

Experimental and numerical investigation of carbon fiber sandwich panels subjected to blast loading Yi Hua et al, studied the structural response of carbon fiber sandwich panels subjected to blast loading. The authors have conducted a total of nine experiments, corresponding to three different blast intensity levels in the 28-inch square shock tube apparatus. The peak reflected overpressure was monitored, which amplified to approximately 2.5 times of the incident overpressure due to fluid structure interactions. As the blast wave traversed across the panels, the observed flow separation and reattachment led to pressure increase at the back side of the panel. Further parametric studies suggested that the maximum deflection of the back facesheet increased dramatically with higher blast intensity and decreased with larger facesheet and core thickness.

Conclusion from experimental testing of blast resistance of FRC and RC bridge decks Marek Foglar and Martin Kovar, studied on experimental testing of blast resistance of FRC and RC bridge decks. The test were performed using real scale precast slabs (0.3 x 1.5 x 6 m) and 25 kg of TNT charges placed in a distance from the slab. The authors have reported that the volumes of the debris in FRC was reduced, the character of the specimen failure was changed from brittle to ductile. Debris of RC structural elements is ejected into surroundings at very high speed and behave like gun-shot projectiles. The results of the experiments are plotted on the spall and breach prediction curve, the RC specimens show agreement with the spall and breach prediction curve, the spall and breach prediction curves are not suitable for FRC. The authors have concluded that the reduction of the volume of debris by fiber insertion represents a significant improvement in overall safety of concrete structures.

Blast-Resistant Design of Structures Manmohan Dass Goel and Vasant A. Matasagar, studied on blast-resistant design of structures. This requires knowledge of (1) intelligent strategies in the form of blast source isolation strategies or using advanced engineered materials, (2) material behavior under such loading, and (3) post explosion functioning of the structure and its elements. The authors have reported various strategies for blast mitigation are reviewed and discussed with an emphasis on presenting a comprehensive assessment of blast response mitigation technologies beginning from the necessary discussion on fundamental aspects of blast-induced impulsive loading and material characterization, especially at high strain rates.

Electrorheological and magnetorheological fluids in blast resistant design applications Ali K. El Wahed et al, studied on the performance of electrorheological (ER) and magnetorheological (MR) fluids under impulsively-applied loads is investigated. The ER fluid device, which is operating in the squeeze flow mode, is tested with four different ER fluids, while the MR fluid device is a commercially available shock absorber in which the flow resistance of the fluid is controlled by a small electromagnetic element. Both devices were tested in an experimental capable of providing fast loading that represents the typical loading of an explosive shock in air or typical loading of a hydrocarbon type explosion. The authors have reported that the performance of the ER fluid device under fast loading could be predicted by a theoretical model based on the assumption of a bi-viscous fluid characteristics.

Integrated design of blast resistance panels and materials Sungwoo Jang and Har-Jin Choi, have studied the performance of BRPs using lighter structures, in order to mitigate the kinetic energy induced by shock waves. The authors have employed a new design approach, using integrated material and a product design which utilizes a distributed framework. This approach eliminates the

inherent limitations of pre-designed materials used in conventional, material-section-based design. The limitations of pre-designed materials used in conventional approach are examined and compared with the new BRP design. An artificial neural network-based material model is introduced to demonstrate the practically and feasibilty of this new design paradigm. Design results of the new BRP are compared to those using conventional material-section-based design. The authors have concluded that the new blast resistant panel was successfully designed, meeting nearly all goals specified.

Blast loading response of reinforced concrete panels reinforced with externally bonded GFRP laminates A. Ghani razaqpur et al, have studied the behavior of reinforced concrete panels, retrofitted with glass fiber reinforced polymer (GFRP) composite, and subjected to blast load is investigated. Eight 1000x1000x70 mm panels were made of 40 Mpa concrete and reinforced with top and bottom steel meshes. Five of the panels were used as control while the remaining four were the remaining four wre retrofitted with adhesively bonded 500 mm wide GFRP laminated strips on both faces, one in each direction parallel to the panel edge. The panels were subjected to blast loads generated by the detonation of either 22.4 kg or 33.4 kg ANFO explosive charge located at a 3-m standoff. The authors have concluded that the GFRP retrofitted panels performed better than the companion control panels while one retrofitted panel experienced severe damage and could not be tested statically after the blast.

Blast Resistance of Double-Layered Reinforced Concrete Slabs Composed of Precast Thin Plates Makoto Yamaguchi et al, have studied blast resistance of double-layered reinforced concrete slabs composed of precast thin plates. 50 mm thick, were fabricated and utilized for contact detonation tests. The tests were conducted under a condition that the amount of explosives and the dimensions of specimens were constant respectively, and two types of concrete, normal concrete and polyethylene fiber reinforced concrete (PEFRC), were employed as the slab materials. The authors reported that the results showed that creating an air cavity between the two layers of PEFRC slab was effective in reducing spall damage, while the air space had no advantage in normal RC, under a condition that the thickness of the air space was fixed at 15 mm.

The response of fibre metal laminate panels subjected to uniformly distributed blast loading G.S. Langdon et al, have studied the response of fibre metal laminate panels (FML) subjected to uniformly distributed blast loading. the FMLs were constructed from aluminium alloy, a polypropylene interlayer and co-mingled glass fibre/polypropylene woven cloth. The spatial loading distribution is approximated as uniform and was generated by detonating annuli of explosive. Observations from blast experiments performed on panels with different stacking configurations are reported and the response compared to similar locally blast loaded FML panels. Multiple debonding, plastic deformation, internal buckling and metal tearing were all observed. In non-dimensional form, the data from both the localised and uniform blast tests collapsed onto one line for the front face displacement and another line for back face displacement.

Performance assessment of steel plate shear walls under accidental blast loads Hassan Moghimi and Robert G. Driver, have studied the performance assessment of steel plate shear walls under accidental blast loads. The potential application of some form of the steel plate shear wall as a protective system in industrial plants possibly subjected to accidental explosions is studied by means of iso-response curves. The constitutive model for the steel material includes mixed-hardening, strain-rate effects, and damage initiation and evolution.The pressure-impulse diagrams for both in-plane and out-of-plane blast orientations, along with the corresponding weight-standoff distance diagrams. A method is proposed to produce dimensionless iso-response curves to broaden their applicability. The results show that despite the inherent slenderness of the steel members, the wall system has the potential to be an effective system for use in a protective structures.

Blast-resistant structural concrete and steel connections Theodor Krauthammer, have studied the Blast-resistant structural concrete and steel connections. A series of numerical studies were conducted on the behavior of structural concrete and structural steel connection subjected to blast loads. These studies gradually enhanced the understanding of the role that structural details play in affecting the behavior. This could be very important when 2D analysis are used to design 3D structures. Observations from those studies highlighted possible safety concerns blast design procedures. Improved design approaches for both structural concrete and structural steel welded connections are needed. Such design approaches should be derived based on additional studies that must be supported by combined theoretical, numerical and experimental efforts.

Experimental study of laminated glass window responses under impulsive and blast loading Xihong Zhang et al, have studied the laminated glass window responses under impulsive and blast loading. Full scale field blast tests were performed on laminated glass windows of dimension 1.5 x 1.2 m. Glass pane deflections were monitored by mechanical linear voltage displacement transducer (LDTV) and high-speed cameras. The responses of the tested windows are compared with the estimations of SDOF models and design standards in this paper. Available blast testing data by other researchers are also included together with the current testing data to evaluate the accuracy of the SDOF and equivalent static analyses defined in the design in the design guides. The adequacy of these simplified approaches in predicting laminated glass window responses to blast loads is discussed.

Blast-loaded behaviors of severely damaged buried arch repaired by anchored CFRP strips Hailong Chen et al, have studied Blast-loaded behaviors of severely damaged buried arch repaired by anchored CFRP strips. A structural model experiment was carried out to check the blast resistance of the repaired arch subjected to underground close-in explosions. The aim of the experiment is to provide believable results of strengthening effects through the dynamic loads, deflections, strains and failure modes. To achieve this objective, blast experiments were performed under 0.6, 3, 2 and 29.4 kg TNT charges, respectively. Applied dynamic loads, strains and the failure modes of the strengthened arch by adhering and anchoring CFRP strips were revealed. Adhering/anchoring CFRP strengthening

measurement is efficient to restrict debonding failure and let the severely damaged arch have comparable load carrying capacity with the intact arch. Two failure modes, concrete spall depending on the tensile strength of the concrete or mortar and structural plastic collapse relating to the reinforcement.

Numerical study of concrete spall damage to blast loads Jun Li et al, have studied the Numerical study of concrete spall damage to blast loads. Fragments of structural element generated from spall damage could eject with large velocities, and impose significant threats to equipment and personnel even it does not necessarily greatly reduce the load carrying capacity of the structural components. Three-dimensional numerical models are developed to predict the concrete spalling under blast loads. The accuracy of the numerical simulations is verified with blast testing data reported by other researchers. Intensive numerical simulations are then carried out to investigate the influences of the column dimensions and reinforcement mesh on concrete spall damage. Based on numerical simulation data, empirical relations are suggested to predict concrete spall damage based on explosion scenarios, column dimensions and reinforcement conditions.

Flexible blast resistant steel structures by using unidirectional passive dampers Habib Saeed Monir, have studied Flexible blast resistant steel structures by using unidirectional passive dampers. If a structure is designed to have high lateral flexibility, the applied passive energy absorbers can dissipate the most internal blast energy. In fact the restoring force of this high flexible frame will not be adequate to return the devices back to their initial dimensions. Therefore, the absorbers lock up the structure at its deflected form which is a very vulnerable condition. This problem has been solved in this research by manufacturing of a new unidirectional passive damper (UPD) which has different behaviors under tensile and compressive loadings. This new damper applies force to the frame and absorbs the energy just in the case that the frame is moving away from its original equilibrium position. When the frame moves toward its equilibrium position, the device becomes inactive and provides no obstacle to the movement of the structure. By application of UPD in a flexible frame, a blast resistant system is achieved in which the internal energy is mainly dissipated by the absorbers.

III. CONCLUSION

Strategies to protect against the blast are divided into two major categories: strengthening of members and protection/mitigation strategies. The emphasis herein has been protection/mitigation strategies, which include mainly increasing the standoff distance from the threat, because the blast pressure decays very rapidly and even a small distance is important. Furthermore, these mitigation measures are less expensive than the strengthening strategies. It can further be noted that the standoff distance can be increased only where sufficient space is available; however, in a city environment, many times it is not possible to adopt the strategies that require space. In such situations, the sacrificial blast wall provides a better solution and can be adopted or designed against an explosive induced threat. The various lightweight materials used for this purpose further add to increase blast resistance in comparison with conventional materials.

REFERENCES

[1] Chengqing Wu., Liang Huang and Deric John Oehlers (2011), " Blast Testing of Aluminum Foam–Protected Reinforced Concrete Slabs". Journal of Performance of Constructed Facilities, Vol.25, pp. 464-474.
[2] Na-Hyun Yi., Jang-Ho Jay Kim., Tong-Seok Han., Yun-Gu Cho and Jang Hwa Lee (2011), "Blast-resistant Characteristics of ultra-high strength concrete and reactive powder concrete". Construction and Building Materials, Vol.28, pp. 694-707.
[3] Shuichi Fujikura and Michel Bruneau (2010), "Experimental Investigation of Seismically Resistant Bridge Piers under Blast Loading". Journals of Bridge Engineering, vol. 16, pp. 63-71.
[4] Tonatiuh Rodriguez-Nikl., Chung-Sheng Lee., Gilbert A.Hegemier and Frieder Seible (2011),"Experimental Performance of Concrete Columns with Composite Jackets under Blast Loading". Journal of Structural Engineering, Vol -138, pp. 81-89.
[5] Pedro F. Silva and Binggeng Lu (2008). "Blast Resistance Capacity of Reinforced Concrete Slabs". Journals of Structural Engineering, Vol. 135, pp. 708-716.
[6] Zahra S. Tabatabaei., Jeffery S. Volz., Jason Baird, Benjamin P. Gliha., Darwin I. Keener (2013), "Experimental and numerical analyses of long carbon fiber reinforced concrete panels exposed to blast loading". International Journal of Impact Engineering, vol. 57, pp. 70-80.
[7] Pedro F. Silva and Binggeng Lu (2006), "Improving the blast resistant capacity of RC slabs with innovative composite materials". Composites, Vol. part B 38, pp. 523-534.
[8] Ben F. Harrison(2013), "Blast resistant modular buildings for the petroleum and chemical processing industries". Journal of Hazardous Materials, Vol.104, pp.31–38.
[9] Tuan Ngo., Priyan Mendis and Ted Krauthammer (2006), "Behavior of Ultrahigh-Strength Prestressed Concrete Panels Subjected to Blast Loading". Journals of Structural Engineering, Vol. 133, pp. 1582-1590.
[10] Ju-Hyung Ha., Na-Hyun Yi., Jong-Kwon Choi and Jang- Ho Jay Kim(2011), "Experimental Study on Hybrid CFRP-PU Strengthening Effect on RC panels Under Blast Loading". Composite Structure, Vol.93, pp. 2070-2082.
[11] Murat Yazici., Jefferson Wright., Damien Bertin and Arun Shukla (2014), "Experimental and numerical study of foam filled corrugated core steel sandwich structures to blast loading". Composite structures, Vol.110, pp. 98-109.
[12] Yi Hua., Praveen Kumar Akula and Limxia Gu (2014), "Experimental and numerical investigation of carbon fiber sandwich panels subjected to blast loading". Composites, vol. 56, pp. 456-463.
[13] Marek Foglar and Martin Kovar (2013), "Conclusions from experimental testing of blast resistance of FRC

and RC bridge decks". International Journal of Impact Engineering, Vol.59, pp. 18-28.

[14] Manmohan Dass Goel., and Vasant A. Matsagar., (2013), "Blast-Resistant Design of Structures". Practice Periodical on Structural Design and Construction, Vol.04014007, pp. 1-9.

[15] 15. Ali K. El Wahed., John L.Sproston and Graham K. Schleyer (2001), "Electrorheological and magnetorheological fluids in blast resistant design applications". Materials and Design, Vol.23, pp. 391–404.

[16] Sungwoo Jang and Hae-Jin Choi (2013), "Integrated Design of Blast Resistance Panels And Materials". Composite Structures, Vol.102, pp. 154-163.

[17] Ghani Razaqpur., Ahmed Tolba and Ettore Contestabile(2006), "Blast loading responses of reinforced concrete panels reinforced with externally bonded GFRP laminates". Composites, Vol. Part B 38, pp. 535-546.

[18] Makoto Yamaguchi., Kiyoshi Murakami., Koji Takeda and Yoshiyuki Mitsui (2011), "Blast Resistance of Double –Layered Reinforced Concrete Slabs Composed of Precast Thin Plates". Journal of Advanced Concrete Technology, Vol. 9, pp. 177-191.

[19] G.S. Langdon., G.N. Nurick and W.J. Cantwell (2008), "The response of fibre metal laminate panels subjected to uniformly distributed blast loading". European Journal of Mechanics, vol. 28, pp. 107-115.

[20] Hassan Moghimi and Robert G. Driver (2014), "Performance assessment of steel plate shear plate shear walls under accidental blast loads". Journal of Constructional Steel Research, vol. 106, pp. 44-56.

[21] Theodor Krauthammer(1999), " Blast-resistant structural concrete and steel connections". International Journal of Impact Engineering Vol. 22, pp. 887-910.

[22] Xihong Zhang., Hong Hao and Zhongqi Wang (2014), "Experimental study of laminated glass windows responses under impulsive and blast loading". International Journal of Impact Engineering, vol. 78, pp. 1-19.

[23] Hailong Chen., Wei Xie., Meirong Jiang., Peng Wang., Jiannan Zhou., Hualin Fan., Qing Zheng and Fengnian Jin (2014), "Blast-Loaded Behaviors of Severely damaged buried arch repaired by anchored CFRP strips". Composite Structures, vol. 122, pp. 92–103.

[24] Jun Li and Hong Hao (2014), "Numerical study of Concrete Spall damage to Blast loads". International Journal of Impact Engineering, vol. 68, pp.41-55.

[25] Habib Saeed Monir (2013), "Flexible Blast Resistant Steel Structures by using Unidfairectional passive dampers". Journal of Constructional Steel Research, vol. 90, pp. 98-107.

