# THE INVESTIGATION OF THE DAMAGES OF BRIDGES SUBJECTED TO THE 2020 FLOOD IN POLDOKHTAR (IRAN)

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**ABSTRACT:** The investigation of the performance of bridges against various natural calamities has always been studied by researchers. Flood is one of the most important natural disasters and its effects on the performance of bridges are always considered. In this paper, the performance and damages of bridges subjected to the 2020 flood were evaluated in Poldokhtar. The studied bridges are including several steel truss bridges, a historic bridge and a bridge with a RC deck and masonry columns. Field studies have been used to investigate the effects of floods on bridges. The result of studied showed that the lack of proper connection of the deck to the abutments and cap beams has been the main reason for the destruction of the truss bridges against floods and the studied truss bridges do not perform well against floods, also it is clear that the masonry columns have a very good performance against the strongest floods due to its circular shape, considerable diameter, integrated structure and the use of breakwaters around them. Besides woods, trees, power transmission towers, etc., which are floating can gather in the front of the bridge and this process can lead to extra pressure on the bridges due to flood. The results of studies can be used in retrofitting the exist bridges, also writing or editing regulations of bridges design against flood.

KEYWORDS: Flood, Truss Bridge, Historic Bridge, Bridge, Bridges Damages

#### 1 INTRODUCTION

Flood is one of the most important natural hazards that has always threatened humans and their settlements. Many parts of the earth are exposed to floods. The risk rate of the flood is absolutely high in Iran, because there are a lot of rivers with different characteristics. A significant part of the Iranian people faced the phenomenon of flood in an irregular cycle and with a permanent scenario and floods are an inseparable part of their lives. Recently, many different studies have been conducted on the effect of flood on the response of bridges and buildings, including those by Middelmann-Fernandes [1]; Serra et

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al. [2]; Holemba and Matsumoto [3] and Martinez-Gomariz et al. [4]. Besides, Brandimarte and Woldeyes [5] examined the uncertainty in the estimation of backwater effects at bridge crossings. Their study aimed at approaching the prediction of backwater effects at bridge crossings by accounting for the main sources of uncertainty affecting the hydraulic modelling exercise. Because of this reason, a bridge over a highly vegetated floodplain was considered for their analysis, and uncertainty in the model parameters and input data was assessed to predict backwater flood design profiles. Shen et al. [6] examined the method for rapidly assessing the overtopping risk of bridges due to flooding over a large geographic region. The objective of their research was to create a screening method able to quickly and inexpensively estimate overtopping risk across a collection of bridges based on the current streamflow conditions. The method was applied to a portion of the Hampton Roads region of Virginia that includes 475 bridges. The results of the analysis, when combined with transportation data for bridges, aid decision makers to assign further resources to complete more detailed analyses of bridges identified as being at risk for overtopping.

Barbetta et al. [7] investigated a reappraisal of bridge piers scour vulnerability. The issue of bridge piers vulnerability to scour was addressed by comparing two procedures. The first method quantifies the Scour Vulnerability Index (SVI) considering the combined effects of local and contraction scour. The study was carried out for a sample of 46 bridges in the Tiber River basin, central Italy, and showed that the two methods identify the same number of piers affected by 'high' vulnerability. Results were supplemented by outcomes of inspections that identified, through the scale factor, a high correlation between measured scour depth and SVI value. SVI, simpler and most practical, seems useful for an expeditious estimate of scour vulnerability in large areas and could be adopted by decision makers to identify the structures requiring attention in terms of maintenance and control.

Prendergast et al. [8] showed that bridges could be subjected to damaging environmental actions due to flooding and seismic hazards. Flood actions that result in scour were a leading cause of bridge failure, while seismic actions that induce lateral forces may lead to high ductility demand that exceeds pier capacity. When combined, seismic actions and scour could lead to effects that depend on the governing scour condition affecting a bridge. Loss of stiffness under scour could reduce the ductility capacity of a bridge but could also lead to an increase in flexibility that may reduce seismic inertial forces. Conversely, increased flexibility could lead to deck collapse due to support loss, so there exists some uncertainty about the combined effect of both phenomena. In their study, various strategies employed to monitor bridge health against scour and seismic actions were discussed, with a particular focus on vibration-based damage identification methods.

Xia et al. [9] studied the hydrodynamic experiments on the impacts of vehicle blockages at bridges. They showed that the obstruction caused by

vehicle blockage at bridges had a significant impact on the hydrodynamic characteristics along the channel center line and the consequent flood risk. As compared with the situation without vehicle blockage, the water depths upstream of the blocked bridges increased significantly for the first two cases considered, while the upstream depths in the third case increased slightly due to the fact that the middle opening of this model bridge was not blocked. Therefore, the impact of vehicle blockage on the depth variations depends on the bridge configuration and the blockage mode.

Wang et al. [10] examined the effects of bridge piers on flood hazards. They showed that bridge piers on river channels could cause obstacles for flood flow by reducing the cross-sectional area and inducing local eddy currents and high flow velocities, which may destroy hydraulic structures. A two-dimensional numerical model was used to investigate the effects of bridge piers on river flood hazards in the Jialing River, China. The influence of backwater effects on the flow field was analyzed by comparing numerical results with and without piers. The results showed that the most significant impacts were caused by the Fengxian Bridge. The maximum water level rose about 1 m and the maximum velocity near this bridge decreased by 22.77% for a 10-year flood.

Cicco et al. [11] investigated the bridge pier shape influence on wood accumulation in terms of experiments and numerical modelling. The results from their research provide a support to design bridge or countermeasures aimed at minimizing wood accumulation at pier shapes typical of historical cities. In this regard, field data on wood transport and accumulation at bridges, were needed. The lack or insufficient field data constitute one of the main problems for researchers. The monitoring activity and the implementation of multiple processes and factors such as sediment transport, the complex nature of log shapes, the number of piers, as well as different river morphologies. Lindt et al. [12] described the development and implementation of the interdisciplinary effort and offered an example of combining an engineering assessment of flood damage to residential structures and social science data to model household dislocation.

Although many studies have been conducted by researchers in recent years concerning the effects of the flood on the damages of the bridges and buildings, some of which were mentioned, a comprehensive study has not been done thus far to investigate the flood on the bridges. Therefore, the effects of the flood (in February 2020 in Poldokhtar) on the response and the damages of the bridges were investigated in this study. For this purpose, at first, the location, the features, the discharge and the risk of the flood for Kashkan River are described. Then, exist information for the flood (in February 2020) is presented. Finally, the performance and the damages of different types of bridges against this flood will be investigated.

# 2 KASHKAN RIVER (LOCATION, DISCHARGE AND RISK OF FLOOD)

Kashkan River basin is located in southwestern Iran with an area of 9276.66 square kilometers. This basin is an important part for providing water of the Karkheh River. After a distance of about 300 km, this river joins to the Seymareh River in the southwest of Poldokhtar in an area called Kalsefid, which make up the Karkheh River. *Fig.1* shows a complete view of the Kashkan River.

There are several hydrometric stations on the Kashkan River. The last hydrometric station of Kashkan River named Poldakhtar was established in 1955, which is shown in *Fig.1*.

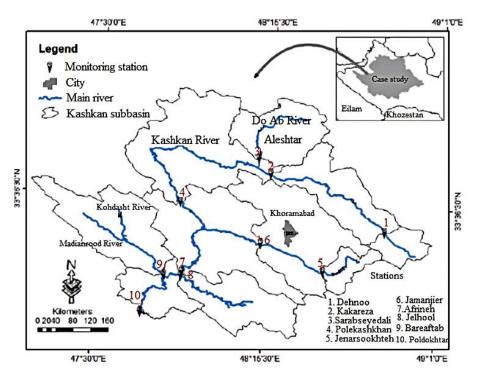


Figure 1. The map of Kashkan River [13]

Fig.2 shows the total annual discharge of the Kashkan River at Poldakhtar station during the years 1984 to 2010. The highest rate of annual flow is in 1992 with 94 cubic meters per second while in 1999, the lowest rate of annual flow occurred that was equal to 20.5 cubic meters per second.

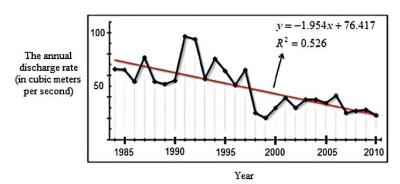
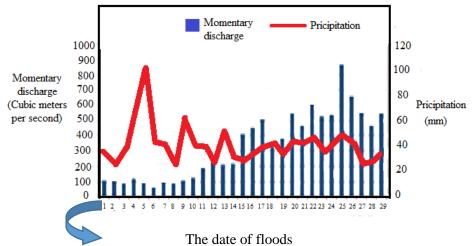


Figure 2. The annual discharge rate of Kashkan River for different years (in cubic meters per second) [14]

However, the Kashkan River has always been a source of blessing for most of people in Lorestan province (who are usually farmers), but the river's neighbors are always at risk of flooding (except in summer) and numerous damages are inflicted on them by floods every year. For this purpose, it is very important to study the characteristics of Kashkan River.



Row	Date	Row	Date	Row	Date	Row	Date
1	1981.10.13	8	1988.12.17	15	1995.03.23	22	2003.02.25
2	1982.12.22	9	1989.12.12	16	1996.01.09	23	2003.10.30
3	1983.12.11	10	1991.01.14	17	1997.11.04	24	2005.03/12
4	1984.11.25	11	1991.12.09	18	1999.03.02	25	2006.02.04
5	1985.11.12	12	1993.10.17	19	1999.12.02	26	2006.03.27
6	1986.11.04	13	1994.02.22	20	2000.03.24	27	2007.04.03
7	1987.12.24	14	1994.11.25	21	2001.12.04	28	2009/03.13
						29	2010.03.12

Figure 3. The comparison of the rate of the precipitation and momentary peak discharge for historical floods in Poldokhtar basin in the period of 1980-2010 [15]

According to *Fig.3* in the Kashkan River Basin from 1999 to 2010, the trend of floods has been increased and the trend of precipitations has been decreased. The momentary peak discharge rate of this basin have increased approximately four to five times from 1999 onwards compared to the previous years.

This fact shows that in recent years, the increase rate of the occurrence of floods is not only dependents on the factor of the rainfall and other factors have a significant impact on it, for example, the change use of the lands, the deforestation, urban development and rural housing development. For example, the amount of the rainfall in the 1980s was higher than it in the 1990s and 2000s, but the volume of the flood flows in the 1980s was much less than it in the 1990s and 2000s.

On the other hand, according to Fig.4, in recent decades compared to the 1980s in Poldokhtar area, the amount of maximum rainfall during 24 hours either reduced or remained steady, however, the trend of severe floods increased.

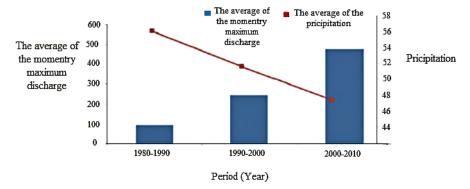
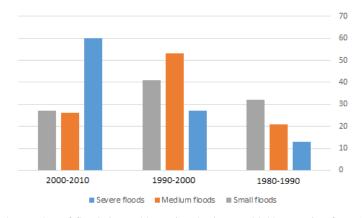


Figure 4. The comparison of the rate of the rainfall during 24 hours and momentary peak discharge in Poldokhtar basin [15]



*Figure 5.* The number of floods in Kashkan River basin at Poldokhtar station from 1980 to 2010 [15].

Fig. 5 classifies the rate of the discharge of the historical floods for the Kashkan River basin based on numerical values, so that, floods are divided into three groups: Strong, Moderate and Minor, with discharges from 700 to 1000, 500 to 700 and 300 to 500 cubic meters per second, respectively.

Examining the issues mentioned above, it is clear that neighbors of the Kashkan River are at risk of flooding in all years and flood is an inseparable part of their lives. Therefore, design of resilient infrastructures against this phenomenon will be very necessary. The characteristics of the floods in February 2020 are described in the following.

# 3 THE INFORMATION ABOUT FORECASTING AND OCCUR-RENCE OF RAINFALL AND MOMENTARY DISCHARGE OF KASHKAN RIVER DURING OF THE FLOOD

#### 3.1 The precipitation forecast

According to the forecasts of the Meteorological Organization for February 26, 2020, the momentary peak discharge in Kashkan River at Poldokhtar station was predicted from 2800 to 4000 cubic meters per second which indicates the anticipated discharge was bigger than the capacity of natural channel of the Kashkan River. It should be noted that the capacity of Kashkan River in Poldokhtar station is equal to 2400 cubic meters per second.

#### 3.2 The occurrence of rainfall

Following the arrival of a heavy rainfall system, unprecedented rains occurred in Lorestan province, so that in about 24 hours, the average of the rainfall in this province was approximately 108 mm and even in some main tributaries of the river was equal to 144 mm.

#### 3.3 The momentary discharge

The hydrometric station of Kashkan in Poldakhtar was built in 1954. Before 2019, the highest rate of the momentary discharge recorded by this station was equal to 3090 cubic meters per second, which occurred in 2005. But in the flood of April 1, 2019, the biggest rate of the momentary discharge at the location of this station was approximately 6500 cubic meters per second. This means that the largest rate of the momentary discharge in April 1, 2019 has doubled compared to the previous floods. But in the flood of February 26, 2020, the maximum rate of the momentary discharge was equal to 3100 cubic meters per second.

#### 4 THE STUDIED BRIDGES

In this study, the damages to a significant number of bridges located in Poldokhtar city due to floods are investigated. For instance, truss bridge in the distance between Doab-Cham Bagh villages, Hayat al-Ghayb village truss bridge, Zivdar village truss bridge, Kalat Zivdar village truss bridge, Kalhor historical bridge and Kalhor RC bridge in Mamolan city, Cham Shahran village truss bridge, Domrud Afrineh village truss bridge and the truss bridge of Cham Mehr village which will be evaluated in detail below.

#### 4.1 The truss bridge between doab and Cham Bagh villages

Due to the flood of 2019, this bridge completely destroyed and its deck fell from its supports. Despite the unsuitable performance of the bridge, a new truss bridge was built with the same structural system and in the same place and on the same substructures. Unfortunately, the new truss bridge was severely damaged by the floods of February 2020. *Photo 1* shows a view of the truss bridge after the flood of February 2020.



Photo 1. A view of the truss bridge between Doab-Cham Bagh villages after the 2020 flood

One of the most important reasons for the destruction of truss bridges against floods is the improper connection of the deck to the cap beams and abutments of the bridge. In  $Photos\ 2$  to 8, the improper connection of the deck to the cap beams and abutments of the bridge is quite obvious. According to  $Photos\ 2$  and 3 and Fig.6, the complete failure of the deck connection to the cap beams has led to a significant horizontal deflection in the deck which the deck is on the verge of falling from the cap beams and abutments. As shown in  $Photo\ 4$ , this improper performance eventually leads to plastic deformation (complex distortions) in the upper beams.



Photo 2. A view of the deck on the verge of falling after the flood



Photo 3. A view of the complex deformations of the deck after the flood

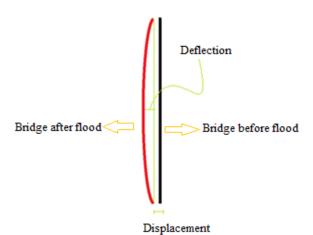


Figure 6. The schematic plan of horizontal displacement and deflection of the deck due to flood



Photo 4. A view of the complex distortions in the upper beam of the truss bridge after the flood

Due to the flood, the deck has been transversely displaced so that according to *Fig.*7 and *Photo 5*, support A fell from the abutment and support B lifted from the abutment significantly.



Figure 7. A schematic view of the behaviour of the beam AB of deck on the abutment due to the flood



*Photo 5.* The left support of the deck fell into the river (without proper connection) and the right support lifted significantly

*Photo* 6 shows the improper connection of the deck to the cap beams and abutments. Photo 7 shows a view of the rotation of the lower beam of the deck on the abutment and *Photo* 8 shows the getting up of support B in the bridge.



Photo 6. The improper connection of the deck to the cap beams and abutments



Photo 7. A view of the rotation of the lower beam of the deck on the abutment

Other factors that have always led to increased pressure on bridges due to floods are the accumulation of wood in front of the deck and also fatal blows of objects floating in water on bridges. The wood of the trees collected in front of the bridge and prevented from the flow of water, and the water collected in front of the deck and puts extra pressure on the bridge. *Photo 9* shows a view of the wood collected in front of the bridge deck.



Photo 8. The getting up of support B



 $Photo\ 9.$  The timber accumulation in front of the deck that can apply extra pressure to the bridge by blocking the water flow path

If in other cases, a bridge is equipped with the seismic bearings, depending on the type of the seismic bearings, the timber accumulation can lead to inefficiency and major damage to the equipment.

In terms of crisis management, rapid assessment of the bridges after floods is very important. Bridges that are unable to provide service should be blocked immediately with warning signs so that their use do not lead to increased damages. It is also important to consider alternative routes for damaged bridges. *Photo 10* shows the passage of villagers through the damaged bridge, which is very dangerous and can lead to irreparable damages.



Photo 10. The dangerous passage of local residents over the damaged bridge

Perhaps the above reasons are a same scenario for the collapse of all truss bridges against floods. The improper design of truss bridges repeatedly leads to the collapse of these bridges in the face of floods, which ultimately lead to significant financial losses.

#### 4.2 Truss bridge of Hayat al-Ghayb village

Due to the flood of 2019, the deck of the truss bridge in the village of Hayat al-Ghayb fell. Without considering any special arrangements or even a detailed inspection and evaluation of the deck, with the repairing the abutment, the deck was placed on it again. As a result, the bridge was completely destroyed due to the 2020 flood, which had far fewer discharges than the floods in 2019. *Photos 11* to 15 showed different views of truss bridge of Hayat al-Ghayb village during the 2020 flood and after its occurrence. *Photo 11* shows truss bridge of Hayat al-Ghayb village before the destruction due to the 2020 flood. According

to *Photo 12*, one of the abutments of the bridge has rotated significantly, which could be one of the reasons of the destruction of the bridge. *Photo 13* shows a view of one of the abutments of the truss bridges in Hayat al-Ghayb village. *Photos 14* and *15* show views of the destroyed bridge of Hayat al-Ghayb village.



Photo 11. Truss bridge of Hayat al-Ghayb village before the destruction due to the 2020 flood



Photo 12. The abutment of Hayat al-Ghayb truss bridge after the 2020 flood, the abutment has significantly rotated



Photo 13. A view of one of the abutments of the truss bridges in Hayat al-Ghayb village



Photo 14. A view of the destroyed bridge of Hayat al-Ghayb village



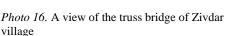
*Photo 15.* Another view of the destroyed bridge of Hayat al-Ghayb village, which showed the distance that the deck has covered due to the flood.

#### 4.3 Truss bridge of Zivdar village

Zivdar village bridge is the only communication route between several villages with a significant number of populations with the Khorramabad-Poldakhtar road. Due to the flood in 2019, the truss bridge of this village was destroyed and the truss bridge shown in *Photo 16* was replaced.

However, the excavation of these channels for the 2020 flood was a breakthrough due to its relatively low discharge and may have been one of the effective reasons for preventing the destruction of the bridge, but it does not seem to be a logical solution for bridges against floods such as the floods 2019 or severe floods, because digging channel near the abutments reduces their resistance and even in some cases leads to instability of the abutments.







 $Photo\ 17.$  The damage to road asphalt

Among the measures considered by the Road Maintenance and Transportation Organization to protect the bridge against the flood was digging two channels in the roads on both sides of the bridge and at close distances to the abutments. *Photo 17* shows that digging the channels has caused damage to the road. *Photo 18* shows a close view of the bridge under study.



Photo 18. A close view of the bridge under study

According to *Photo 19*, if the bridge is divided into two different spans, the span BC with two the seismic bearings (Lead rubber bearing) is connected on the abutments, but according to *Photos 20* to 22, the span AB from the starting point of the bridge (point A) to the support B does not have any support connection system and the bridge is placed on the slab without any connection.





Photo 19. The division of the bridge into two spans AB and BC



Photo 20. The different views of point A



Photo 21. A view of point B



*Photo* 22. A view of the span AB from the studied bridge, it can be seen that only point B of this span of the deck has a connection system to the substructure and other parts of the truss are located on the substructure without any connection system.

# 4.4 Truss bridge of Kalat Zivdar village

Due to the flood 2019, truss bridge of Kalat Zivdar village destroyed, which can be observed the columns of this bridge in *Photos 23* and *24*. The new bridge was built with a higher height to increase the possibility of its stability and also the deck of the bridge will not be affected by flood pressure in the near future. According to *Photo 25*, the interesting point is that the new bridge columns was built on the columns of the previous bridge.



Photo 23. The columns of Kalat Zadar Bridge after the deck overturned due to floods in 2019 (Photo by Morteza Ghasemi-Nia)

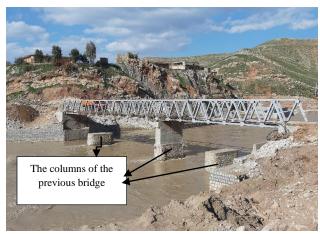


Photo 24. A view of the columns of the previous bridge



Photo 25. The construction of columns of the new bridge on the previous bridge columns

The truss bridge shown in *Photo 26* was constructed a year ago. Prior to the recent floods, the Road Maintenance and Transportation Organization facilitated water passage by digging two channels on roads on both sides of the bridge but this led to the complete collapse of the roads on both sides of the bridge, as shown in *Photos 27* and 28.



*Photo 26.* A view of the truss bridge of Kalat Zivdar village during the 2020 flood (Photo by Morteza Ghasemi-Nia)



Photo 27. The destroyed road on both sides of the bridge



Photo 28. The complete destruction of the road on both sides of the bridge

However, digging the channels has led to the collapse of the road on both sides of the bridge, but the bridge was not significantly damaged by the floods. Immediately after the flood, the road reconstruction operation started, the process of which is shown in *Photos* 29 to 31.



*Photo 29.* The created channel on the road to facilitate the passage of water around the bridge and reduce the pressure on the bridge due to flooding



Photo 30. The process of repairing a destroyed road



Photo 31. A view of the uninterrupted operation of the bridge after the 2020 flood

If properly designed, digging channels around bridges against floods can be very helpful. This action requires that (according to the regulations or calculations, tests and performed modeling) the distance of the channels from the abutments be selected that does not have negative effects on the performance of the abutments. In addition, it is necessary for these channels to be designed and implemented before the flood, not during the floods.

*Photo 32* shows how wood and other materials in the water could collect before the bridge which ultimately leads to extra pressure on the bridge.



Photo 32. A view of the gathering of wood on the deck

#### 4.5 Kalhor historical bridge

The Kalhor historic bridge and the Kalhor RC bridge are located close to each other. *Photo 33* shows views of these bridges when they were affected by the 2020 flood. Kalhor historical bridge was very resistant to flood due to its thick columns and the presence of breakwaters around its columns and no significant damage was caused to the bridge by the flood. *Photos 34* and *35* show views of the Kalhor historic bridge after the 2020 flood.



Photo 33. A view of the historic bridge and the RC bridge during the flood 2020



Photo 34. Views of the historic bridge and the RC bridge after the 2020 flood

Despite the fact that the Kalhor RC bridge was completely submerged due to the 2020 flood and also due to its location was under the influence of water flow with the highest speed and intensity, which showed a very good performance.

Actually, except for the limited damages on the road on both sides of the bridge, which could be reconstructed quickly, it did not suffer significant damage, which could be due to the proper design of the bridge (especially the proper connection of the deck to the cap beams and abutments).





Photo 35. Views of one of the column of Kalhor historic Bridge, located in the middle of river after the 2020 flood

### 4.6 Kalhor Bridge with RC deck and masonary columns

The deck of Kalhor Bridge is made of reinforced concrete and it columns are made of masonry material, and it is only way to connect more than ten villages with the Khorramabad-Poldokhtar road. However, the height of the bridge piers is very short and usually in all floods the river water level is higher than the bridge deck, but this bridge had always shown considerable resistance, so that in the flood of April 2019 and the flood of February 2020, it had maintained its uninterrupted service capability.

Although parts of the road on both sides of the bridge was always destroyed by floods, but this bridge does not suffer major damage and has the ability to provide uninterrupted service after the flood.

*Photo 36* shows a view of the damage to the road, which has been partially repaired, and *Photo 37* shows the uninterrupted service ability of the bridge with the trucks passage.





Photo 36. Views of the studied bridge





Photo 37. Views of the uninterrupted service ability of Kalhor Bridge after the 2020 flood with the frequent passing of trucks over it

Despite the short length of the bridge, its deck has four very strong supports (two columns and two abutments), which was one of the main reasons for the bridge's resistance to the flood.

# 4.7 Truss bridge of Cham Shahran village

The truss bridge of Cham Shahran village built a year ago. The deck of the bridge overturned due to the February 2020 flood. The view of this bridge is shown in *Photo 38* and in *Photo 39* a view of the deck after flood is shown and in *Photos 40* and *41* the abutments and columns of the bridge are shown.



Photo 38. A view of the truss bridge of Cham Shahran village before the peak time of flood



Photo 39. A view of the bridge deck of Cham Shahran village after the flood

Digging the channel on both sides of the roads were connected to the bridge in order to more pass water and reduce water pressure on the bridge did not prevent the deck from falling and the deck overturned. The deck of the bridge also fell due to its improper connections to columns and abutments.

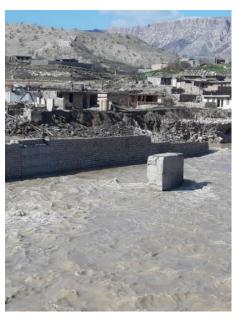


Photo 40. A view of the abutment and column in Cham Shahran Bridge after the 2020 flood



Photo 41. Another view of the abutment in Cham Shahran Bridge after the 2020 flood

It is noteworthy that the truss bridge of Cham Shahran village destroyed by the 2019 flood and a new truss bridge with the same structural system was used at

the same point, which was also destroyed by the February 2020 floods. This result indicates that the causes of damage to the bridge should be assessed before proceeding to repair the bridges or replace the damaged or destroyed bridges with new ones and the best solution should be used to prevent the recurrence of damages.

#### 4.8 Truss bridge of Domrud Afrineh village

One of the most important issues in designing bridges against floods is to consider the topographic effects of the site. The design of bridges against floods in mountainous areas is very different from the design of bridges in plain areas due to the existence of many mountains and valleys in the region. In mountainous areas, due to topographic characteristics and the presence of mountains and valleys, the speed and intensity of water during floods is usually much higher than plain areas. In fact, in mountainous areas the flow of river water strikes the structures with considerable depth and intensity, but in the plains, due to the low altitude of the areas, the river water is usually spread there at a low speed and only the water level rise.

Although Poldakhtar city in Lorestan province is considered as a mountainous area, but the bridge located in the village of Domrud Afrineh was built in a plain area where the flooded water flows passed from the river along a very wide path and at a much slower relative speed. For this reason, the truss bridge in the village of Demrud Afrineh (although it has the same structural system with the other truss bridges destroyed) did not fail during the February 2020 flood.

*Photo 42* shows the water level of the Kashkan River in the 2020 flood relative to the bridge, and *Photo 43* shows the significant width of the water flow.



Photo 42. A view of the water level of Kashkan River in the 2020 flood



Photo 43. Truss bridge of Domrud Afrineh village in the 2020 flood

# 4.9 Truss bridge of Cham Mehr village

After the destruction of the bridge of Cham Mehr village due to floods in 2019, for various reasons, including the high population of this village and the high speed of construction of truss bridges, it was decided to build a truss bridge for this village which is seen in *Photos 44* to 47. It is noteworthy that the columns of the new bridge were built on the columns of the previous bridge. *Photo 51* shows the use of two structural systems for the deck in this bridge. *Photo 52* shows a view of the bridge under construction in Cham Mehr village before the 2020 flood. *Photos 46* and 47 show views of the truss bridge of Cham Mehr village before the 2020 flood.



Photo 44. The use of two structural systems for the deck in the truss bridge of Cham Mehr village



Photo 45. A view of the truss bridge under construction in Cham Mehr village before the 2020 flood



Photo 46. Another view of the truss bridge of Cham Mehr village before the 2020 flood

According to *Photos 48* and *49*, due to the 2020 flood, in order to prevent the destruction of the bridge, the Road Maintenance and Transportation Organization decided to remove a number of span of bridge. According to *Photo 50*, due to this flood, the road connected to the bridge was completely destroyed in a considerable length, and according to *Photo 51*, after the flood, route reconstruction operations were carried out.

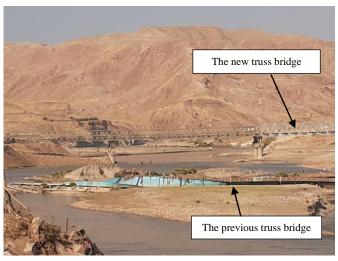


Photo 47. Another view of the new truss bridge in Cham Mehr village before the 2020 flood



*Photo 48.* View of the separated parts from the truss bridge of Cham Mehr village by the Road Maintenance and Transportation Organization



*Photo 49.* Another view of the separated parts from the truss bridge of Cham Mehr village by the Road Maintenance and Transportation Organization



Photo 50. A view of the destruction of the road in Cham Mehr village after the 2020 flood



Photo 51. A view of the road repair process

Among the solutions taken to reduce the damage caused by this flood, the removal of all or part of the deck of truss bridges was before the flood. However, this solution may be useful in the short term and the bridge can be quickly re-installed after the flood, but human beings today needs to infrastructures with high resilience to various types of natural disasters that can maintain their uninterrupted performance against them.

## 5 CONCLUSION

In this paper, the effects and damages of the flood of February 2020 on the bridges located in Poldakhtar city were investigated and finally the following results were obtained:

- The studied truss bridges do not perform well against floods.
- As far as possible, the truss bridge system should not be used in areas with high risk of flood.

- To build a truss bridge on rivers with high risk of floods, it is recommend that the deck is not in contact with floods and the height of its columns be very long. Also, the use of a very strong connection system to connect the deck to the cap beams and abutments is very crucial.
- The lack of proper connection of the deck to the abutments and cap beams has been the main reason for the destruction of the truss bridges against floods.
- The connection of the deck to the abutments and cap beams must be designed against the phenomenon of the fatigue, because the pressure caused by the flood may for hours applied different loads on various joints of bridges.
- -The amount of length of the parts of the deck that are on the cap beams and abutments is very important, also the strength of the elements that restrict the transverse movements of the deck on the cap beams and abutments is very vital. In case of failure of the connection system between the deck with the cap beams and abutments, it is possible to prevent the deck from falling with their help.
- The channel excavated around the truss bridges in this study due to very close distance between these channels to the abutments can be one of the main causes of damage to some truss bridges. Proximity of the channel to abutments may lead to scour, instability, rotation, and reduce resistance of abutments against the flood.
- In plain-like areas due to the lowlands of these areas and the spread of flooded river water in the plains, floods usually do not cause significant damage to bridges. Because the speed and intensity of water release in these areas is relatively lower than in mountainous areas, but in mountainous areas, floods have significant effects on bridges and this fact indicates the vital role of topographic effects in the design of bridges against floods.
- The channels digging in mountainous areas can be more useful than plain areas because in plain areas, usually due to the low altitude of the adjacent lands to the river, the digging the channels will not be effective.
- -Woods, trees, power transmission towers, furniture, etc., which are floating on the water, can gather in front of the bridge due to floods and prevent water from passing under and over the bridge. This process can lead to extra pressure on the bridges. Also, the conflict of these objects to the bridges can have fatal blows on the bridges.
- One of the column of the Kalhor ancient bridge, which is located inside the Kashkan River, has not been significantly damaged by the recent floods. The column of this bridge showed a very good performance against floods due to its circular shape, considerable diameter, integrated structure and the use of breakwaters around it.
- By examining the Kalhor RC bridge and the historical bridge of Kalhor, it is clear that the masonry columns have a very good performance against the strongest floods.

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