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Investigation of the Causes and Condition of Bridges Deterioration for Effective Maintenance in Salangs-Afghanistan

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Abstract

In recent years, bridge deterioration and the risk of failure have been a continuing challenge for transportation infrastructure in Afghanistan. This paper intends to study the main causes and conditions of bridge deterioration in Salngs. Firstly, the common factors resulting in bridge degradation and may contribute to their failure are briefly explained. The factors are classified as natural factors (scour, flood, landslide …etc.) and human factors (collision, overloading, lack of inspection and maintenance… etc.). Then, the deterioration modes, type of deficiencies, and structural condition of each single bridge were discussed. The present study indicates that deterioration due to lack of maintenance, scour, overload, and design error are the most commonly encountered in bridges, followed by collision and construction errors. The findings obtained through the study of the deterioration of these bridges prove to be of great value as this study provides adequate information to enhance preventive maintenance approaches to avoid contributions to bridge failure. Additionally, this paper concludes with a discussion of bridge prioritization based on their degradation modes for effective maintenance and management in Salangs.

Keywords: Bridge, Deterioration, Maintenance, and management**.**

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1. Introduction

Integrity, safety, and serviceability of bridges and viaducts are all fundamental targets that need to be guaranteed during their lifetime, owing to the crucial role that such infrastructure components play in the (highway and railway) transportation system [1]. Today, road networks and bridge systems play an important role in the connection of different regions. It also facilitates trade and cooperation between areas and the globe. Normally, bridges during their design life may need rehabilitation, replacement, and maintenance for several reasons: deterioration of bridge materials, accidents, drainage, debris, vegetation, scouring of foundation, movement of the structure, and condition approach [2]. Bridges may also become overcrowded or no longer able to carry heavier trucking loads, making their functionality obsolete. Furthermore, bridges are rather costly to design, construct, maintain, and rehabilitate. Thus, preventive maintenance and management have been introduced to address this challenging issue [3].

Recently, bridge degradation and the risk of failure have been a continuing challenge for most of the transportation infrastructure in Afghanistan. The Ministry of Public Work (MoPW) of Afghanistan roughly estimated 20,849 bridges and culverts exist across the country, among them 29 bridges are located in the south and north Salangs. Most of the bridges are degraded and require urgent maintenance and repair. Figure 1 shows the number of bridges in Salangs, there are 24 composite bridges and 5 reinforced concrete (RCC) which total reached 29 bridges [4].

Generally, the factors contributing to bridge deterioration and overall structural conditions degradation are categorized as deficiencies according to various phases in design, construction, maintenance, use of low-quality materials, and inadequate consideration of external events. In this paper, initially, the common causes of bridge degradation and failure are explained to provide a complete illustration to compare them with the Salangs bridge deterioration for deep investigation. Then, the deficiencies of all bridges and conditions were discussed. Finally, the causes of bridge deterioration have been categorized based on the common deficiencies available to further simplify the bridge maintenance and management, also this provided sufficient information for road inventory and civil engineers. Moreover, this paper described the causes of bridge deterioration numerically based on percentages to give well priorities for maintenance. This study also summarized the bridges while considering degradation intensity namely: bridges not need maintenance, normal maintenance, immediate maintenance, and bridges that require construction. Consequently, it may help engineers and bridge inventory to develop sophisticated, accurate, and real planning for appropriate bridge repair and management.

This research aims to investigate the causes and conditions of bridge deterioration based on the actual situation in Salangs, and the most common factor that contributes to bridge degradation has been identified for well categorization and maintenance.

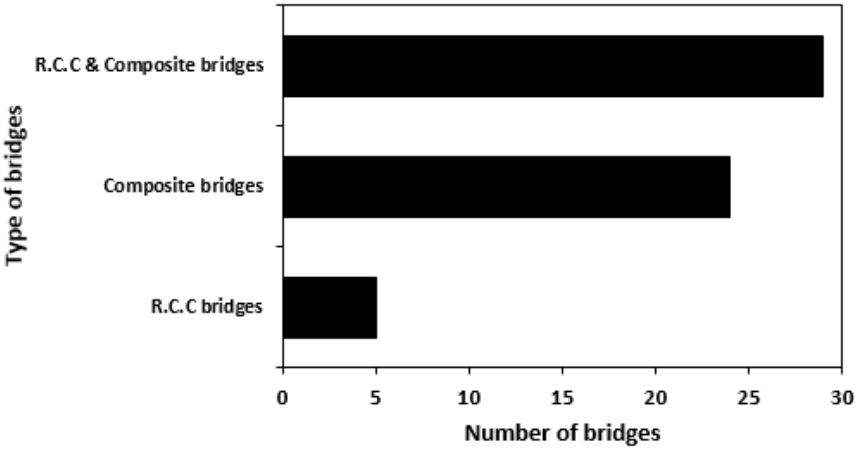


Fig. 1. Type and total number of bridges in Salangs

2. Causes of Bridge Deterioration and Failures

2.1. Natural Factors

Many natural disasters such as floods, scour, earthquakes, landslides, debris flow, hurricanes, and typhoons, are often uncontrollable that partially or may completely devastate bridges. A summary made to illustrate the bridge deterioration and failure factors as follows:

2.1.1 Flood

Normally, heavy precipitation produces flooding, that may cause phenomena like scour, erosion, river convergence, insufficient embedment depth, protection works-induced hydraulic jump, softened bedrock, sand mining, debris impact, or abrasion on bridge foundations [5].

2.1.2 Scour

Scour is a phenomenon in which the level of the river decreases under the effect of water erosion, leading to the exposure of bridge foundations [6]. This is either due to increasing flow speed around the river piers or the long-term erosion of the riverbed. The lateral resistance of the soil supporting the foundation is significantly reduced by increasing scour depth, thus increasing the lateral deflection of the foundation head. Moreover, when the critical scour depth is reached, bending buckling of the foundation may happen under the combined effect of the dead load of the bridge superstructure, the traffic load, or later loads.

2.1.3 Landslide

Due to water saturation, mainly landslides take place, earthquakes, or volcanic eruptions, and result in the downward and outward movement of slope-forming materials including rock, soil, artificial fill, or a combination of these materials [7]. These moving slope-forming materials, when hitting the bridge, will lead to serious damage or even destruction of the bridge.

2.1.4 Earthquake

Earthquakes make horizontal and vertical ground motions that cause bridge failure. Most of the damage comprises shear-flexure failure of the bridge pier columns, shear keys failure, expansion joints failure, and girder sliding in the transverse or longitudinal directions as a result of weak connections between girders and bearing [8]. Furthermore, the horizontal and vertical ground motions perhaps cause the liquefaction of the soil at the bridge foundations which can significantly reduce the load-carrying capacity of the foundations leading to bridge collapse.

2.1.5 Debris Flow

A debris flow exerts tremendous impact forces on the obstacles in its way, particularly when large stones are transported. Also, a growing debris flow has serious erosive effects. Thus, when large-scale debris flows past the site of a bridge, the damage to the bridge could be destroyed [9].

2.1.6 Wind

Wind-induced aerostatic and aerodynamic forces are major challenges in the design of bridges, especially for long-span and flexible bridges [10]. Aerostatic instability is also divided into two types based on the modes of static instability, which are called torsional divergence and lateral-torsional buckling [11]. Aerodynamic vibration is created through three different kinds of oscillations, flutter, buttering, and vertex-induced oscillation [12]. These forces make large displacements and stresses that may exceed the capacity of bridge structures and result in bridge collapse.

2.2. Human Factors

In addition to natural factors, human factors, consisting of imperfect design and construction methods, collision, vehicle overloading, fire, blast load, lack of inspection and maintenance, etc., may also cause bridge deterioration and failure. The factors can be summarized in the following sections.

2.2.1 Imperfect Design and Construction Method

Many bridges have deteriorated as a result of the imperfect design; the use of materials with poor quality use of an inappropriate construction method has led to even collapse in the construction phase [13, 14]. The use of material based on location and environmental factors plays an important role. Steel bridges don’t have sufficient resistance when exposed to corrosive weather.

2.2.2 Vehicle Overloading

Vehicle overloading has become more and more common as a result of increasing competition in the transportation market and has serious concerns [15]. Truck overloading usually causes fatigue problems in bridge components and decreases the service life of bridges. [16].In some extreme cases, the weight of the overloaded trucks

may exceed the load-carrying capacity of the bridge and directly cause bridge deterioration and collapse.

2.2.3 Collision

Collision due to vessel impact causes severe damage to bridges. Accidental collisions between vehicles and bridge superstructures and vessels and bridge columns or piers cannot be predicted. When collisions occur, huge forces are transmitted to the impacted bridge structures [17]. Local damage to the bridge components usually happens due to very high local pressure produced by the large impact force, acting on a relatively small contact area. Moreover, as the bridge absorbs the dynamic collision energy, significant inertial forces and vibrations will be developed. Collision forces can, therefore, lead to serious damage to bridge components.

2.2.4 Lack of Inspection and Maintenance

Mainly, bridges are designed and constructed to serve for a long time, almost 100 years. Bridges in service are constantly subjected to not only dead and live loads but also exposed to aggressive environments. Hence, bridges experience constant deterioration, when exceeding a certain threshold level, which results from serious problems. The deterioration mechanism is influenced by various factors including material properties, environmental conditions, and live load situation [18]. The risk of bridge deterioration cannot be eliminated, however, a good maintenance program including regular inspection and proper rehabilitation will slow down this process [19].

2.2.5 Fire

Fire on bridges is commonly caused by the collision of vehicles such as fuel tankers or freight trucks and multiple vehicle collisions or construction accidents[20]. Increasing temperature (in the range of 800-900℃) within the first few minutes of fire imitation and then the temperature can rise to 1000℃ or higher in the first 30 min [21]. Large thermal gradients in the structural member can be created due to the rapid temperature rise, consequently, making spalling of the concrete and local buckling of steel members. Furthermore, fires can lead to a significant decrease in the load-carrying capacity of the structural members owing to a reduction in the strength and stiffness of materials that can further lead to partial or full collapse [20].

3. Description of bridges in Salangs

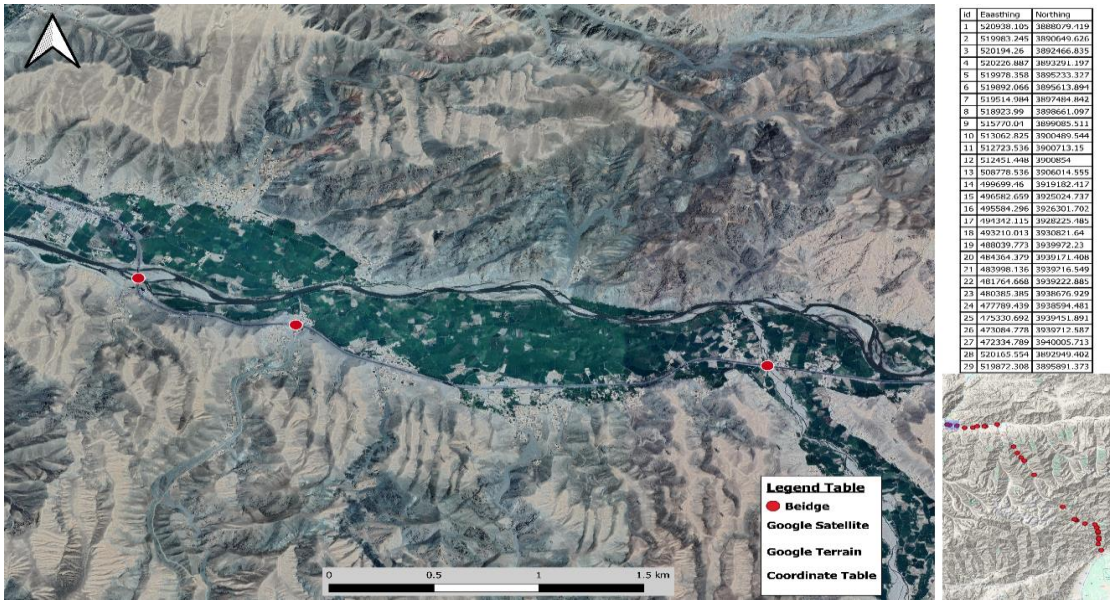
In Afghanistan, the Salangs highway between Kabul-Mazar-e-Sharif is the main route across the Hindu Kush mountain range. It has been in use as a trade route between central Afghanistan and the northern region. This highway made a critical part of the transport infrastructure in the country. The total length of Salang is 108 km, which is 42 km south of Salang, 2.6 km comprising the Tunnel itself, and 63.4 km north of Salang, the tunnel is located at an altitude of 3400 m. 29 bridges exist in the entire Salangs, among them 14 bridges are located in the north and the 15 bridges are situated in the south. The bridges are made of both reinforced concrete and composite types, for more details of the bridges names, types, wide, number of spans, length, and the total length

are given in Table 1. The Salang highway has experienced heavy traffic since construction, the daily traffic has reached almost 4500 to 6000, and most heavy-loaded trucks use this highway causing bridge infrastructure degradation [4], the study bridge locations are shown in Figure 2.

Although integrity, safety, and serviceability of bridges and viaducts are all fundamental targets that need to be guaranteed during their lifetime, owing to the crucial role that such infrastructure components play in the (highway and railway) transportation system, the bridges located in Salang cannot function well to provide convenient transport passage. However, for a long time, many efforts have been made to seek alternative routes of Salangs to connect the north with the central but still, it is the shortest route compared to others and needs to be focused on their bridge infrastructure for rehabilitation, repair, and maintenance. The other factors that elevate the value and attract attention to know about this route are the low temperature, heavy rainfall, and existing fog during the year particularly in the months of October to April. It means, in addition to improper functionality of bridge infrastructure the weather and geographical topography create problems to some extent for transportation services.

Table 1. Shows the geometry description and type of study bridges in the north and south Salnags

No	Bridge Name	Type of bridge	Locations (Salangs)	Wide (m)	Number of span	Length of span(m)	Total Length(m)
1	Tajikan	Composite	South Salang	6.9	1	22	22
2	Bagh-lala	R.C.C	//	10	1	14.2	12.4
3	Baba-Mardan.1	R.C.C	//	-	1	Missed	-
4	Baba-Mardan.2	R.C.C	//	7.15	1	14	14
5	Deh-Naw	Composite	//	7.3	1	32.6	32.6
6	Peja.1	Composite	//	7.3	3	missed	-
7	Peja.2	Composite	//	7	1	32.75	32.75
8	Pole-Aghile	Composite	//	7.1	1	21.7	21.7
9	Pole-Qalatak	Composite	//	8.45	1	32.8	32.8
10	Haya-Jan	Composite	//	7.2	1	23.3	23.3
11	Derbandi	R.C.C	//	7.6	1	14.2	14.2
12	Crafted-Khana. 1	Composite	//	7.3	1	32.4	32.4
13	Cafter-Khana. 2	Composite	//	7.1	1	33	33
14	Owlang	R.C.C	//	11	2	16.5	33
15	Doshakh	Composite	//	7.1	1	21.7	21.7
16	Freshtagan	Composite	North Salang	7.2	1	46	46
17	Malkhan	Composite	//	7.35	1	46	46
18	Hesar	Composite	//	7.45	1	46.3	46.3
19	-	Composite	//	7.5	1	33	33
20	Chowgani	Composite	//	7	1	21.9	21.9
21	Walyan	Composite	//	7	1	32.7	32.7
22	Gaza-khial. 1	Composite	//	7	1	32.6	32.6
23	Gaza-khial. 2	Composite	//	7	1	22	22
24	Gerow	Composite	//	7	2	21.8	43.6
25	Bid-Dara	Composite	//	7	2	22	44
26	Daraze-Dara	Composite	//	7	1	22.6	22.6
27	Khoja-Zaid	Composite	//	7	2	22	44
28	Coka	Composite	//	7	1	22	22
29	Doshi	Composite	//	7	4	32.6	130.6



id	Eastthing	Northing
1	520938.105	3888079.419
2	519983.245	3890649.626
3	520194.26	3892466.835
4	520226.887	3893291.197
5	519978.358	3895233.327
6	519892.066	3895613.894
7	519514.984	3897484.842
8	518923.99	3898661.097
9	515770.91	3899085.511
10	513062.825	3900489.544
11	512723.536	3900713.15
12	512451.448	3900854
13	508778.536	3906014.555
14	499699.46	3919182.417
15	496582.659	3925024.737
16	495584.296	3926301.702
17	494342.115	3928225.485
18	493210.013	3930821.64
19	488039.773	3939972.23
20	484364.379	3939171.408
21	483998.136	3939716.549
22	481764.668	3939222.885
23	480385.385	3938676.929
24	477789.439	3938594.481
25	475330.692	3939151.891
26	473084.778	3939712.587
27	472334.789	3940005.713
28	520165.554	3892949.402
29	519872.308	3895891.373

Fig. 2. Shows the location of bridges in Salang highway
(Image generated using GIS)

4. Evaluation of Bridges Deteriorations and Conditions in Salangs

Most bridges are degraded as a result of various factors in salangs. Some of them need either immediate maintenance or new construction. In the present study, an investigation was conducted to inspect each single bridge by field measurements to describe the existing technical deficiencies and conditions for appropriate maintenance and management. The investigation began from the first bridge namely Tajikan till the end of the Doshi bridge which is located in the Parwan and Baghlan provinces respectively.

Here, a few numbers of bridges are focused on as examples to illustrate the more usual types of deterioration. As indicated in Figure 3A, this bridge is located quite in a sharp horizontal curve due to topographical restriction. Figure 3B, shows the bridge overview from beneath the girders, the yellow circle demonstrates the bridge end span on the abutment where the girder has been displaced laterally due to the passage of heavy vehicles, this occurs when the front axle of vehicles pass from the bridge, then directly enter the curve and the back axles significantly pull the slabs and girders in one side. In other words, the girders of the bridge are subjected to horizontal forces owing to the vehicle's axle, and the girders tend to slowly slide from the bearing pad. Similarly, figure 3C shows the same problem in other bridges. As it is seen obviously from the figure the girders have been displaced laterally from left to right side and tend to slide from the bearing pad, this bridge as well as bridge figure 3B is exposed to a quite similar problem.



(A). Bridge from top view and location



(B). Bridge layout from beneath



(C). Lateral movements of girders



(D). Bearing pad condition



(E). Erosion/Scour of pier foundation



(F). Diaphragm broken & pier damaged



(G). Slab broken



(H). Slab surface and guardrails conditions

Fig. 3. Shows typical cases of bridge deterioration in north and south Salangs

Additionally, the existing situation of the bearing pad is shown in Figure 3D, these bridges are totally at risk of collapsing, and other similar cases were observed during the field investigation. Furthermore, the bearing pads are in worse condition and damaged. As it is seen clearly, the bearing pad seems broken, and weak in load transformation and will no longer resist load carrying as well. According to Figure 3E, scour and erosion have occurred around the pier foundation and still the riverbed is devastating due to the sharp slope and flow speed. Additionally, the water flow tends to continue only from one side and has changed its normal pattern. Also, in many other bridges similar problem has been observed which requires protection against scouring and erosion.

Figure 3F shows the bridge condition from beneath of superstructure, many of the diaphragms have been broken and the slabs and girders have independent movement, when the girders don't have sufficient diaphragms within each other, the girder may have independent behavior, thus, vibrations can be produced in the bridge as a result of girder independent movements to some extents, this bridge needs to be newly constructed. Moreover, many other problems were observed in other bridges such as; broken slabs, damage to expansion joints, guardrails, abutments filled through debris, riverbed erosion, debris flow, and so on. Figure 3G indicates, the existing slab condition and deficiencies, this slab is a precast type and after production has been assembled in the field. Based on the figure some of the slabs are completely broken, and many holes and cracks appear which are needed to be replaced. Figure 3H demonstrates the existing situation of the bridge from the top. As the figure indicates, the slab surface has been damaged even though the slab rebar is exposed and uncovered, The guardrail is damaged on the left edge of the bridge slab, and on the right edge doesn't exist, expansion joints including the sidewalk are significantly devastated as well. Hence, it is concluded that the slab surface, sidewalks, guardrail, expansion joints, and drainage including riverbed sediments are in worse condition and need complete rehabilitation and repairs.

To summarize the following discussion and explain the causes of degradation for each single bridge clearly, the deficiencies and condition of the bridge have been explained in Table 2. Based on the descriptions of this table almost all of the bridges are deteriorated except bridge number three which has been built recently. The reason for deterioration and type of deficiencies were noted for each element of the bridge structure and the condition was shortly described. Then, for more accurate inspection and classification of deterioration reasons, all bridges were categorized based on deterioration sources as shown in Table 3. That is to say, all the degradation of bridges mostly falls within five categories in Salangs, and the other types of deterioration are extremely less or their influence is not significant. Table 3 helps to make a summary of all similar causes of bridge degradation under single categories for easy studying, repairing, and construction. Finally, it is mentionable that all photos used in this study were taken through an iPhone Camera, model name X_R, photo quality 72 dpi, 24 bit.

Table 2. Bridge Deficiencies and Conditions in Salangs

No	Bridge Name	Reason of Deterioration
1	Tajikan	The slab is partially devastated, expansion joints and slab surface are in worse condition. Drainage is closed and guard rails have been damaged.
2	Bagh-lala	The guardrail and expansion joints are damaged. Drainage is blocked.
3	Baba-Mardan. 1	Newly constructed and the condition is completely well.
4	Baba-Mardan. 2	The girders are damaged, the diaphragm is partially cracked & approach slab is in the worst condition.
5	Deh-Naw	Girders have horizontal movements, and expansion joints, guardrails, and approach slabs are damaged.
p6	Peja.1	Scouring of around pier, existing deep cracks at the foundation, and damage of expansion joints, guardrail including approach slab.
7	Peja.2	Damage to the guardrail, sidewalk, expansion joints, slab surface, approach slab, and existing debris and sediments including slab vibrations.
8	Pole-Agile	Having slab vibration and also approach slab, guardrail, and sidewalk are damaged.
9	Pole-Qalatak	Scouring of the foundation, existing vibration in the slab, and sidewalk including the guardrail are damaged.
10	Haya-Jan	Existing damages on slab surface, sidewalk, guardrail, expansion joints, and also its slab including sediment of the riverbed.
11	Derbandi	Slabs and diaphragms are in worse condition including the guardrail. Also, there is vibration in the slab.
12	Cafter-Khana. 1	Girders have horizontal movements, and expansion joints, guardrails, and approach slabs are damaged. The drainages are blocked including having sediment in flow direction.
13	Cafter-Khana. 2	Damage to the guardrail, sidewalk, expansion joints, slab surface, approach slab, and existing debris and sediments including slab vibrations.
14	Owlang	The guardrail, sidewalk, expansion joints, slab element, and approach slab are destroyed. Existing debris between girders.
15	Doshakh	Expansion joints, sidewalks including slab surfaces have been partially devastated.
16	Freshtagan	Vibration in the slab, approach slab, expansion joints, and some parts of the guardrail are ruined.
17	Malkhan	Expansion joints, slab surface, drainage, and guardrail are ruined to some extent including having vibration in the slab.
18	Hesar	Having rutting, and cracks in slab surface. Expansion joints have damage and a little vibration was observed.
19	-	Totally destruction of guardrail, expansion joints, and sidewalk are partially destroyed.
20	Chowgani	Guardrail, expansion joints, and sidewalk including slab paving are damaged.
21	Walyan	Same
22	Gaza-khial. 1	Same
23	Gaza-khial. 2	Same
24	Gerow	The wing wall, middle pier, guardrail, expansion joints, and sidewalk including slab pave are damaged.
25	Bid-Dara	The approach slab and paved slab are destroyed.
26	Daraze-Dara	The approach slab and paved slab including the guardrail have been ruined to

		some extent.
27	Khoja-Zaid	Same
28	Coka	Damage was observed in the guardrail, paved slab, and bridge slab.
29	Doshi	Existing cracks in the slab, expansion joints, and guardrail including the paved slab are partially destroyed.

Table 3. Classification of Bridges Deterioration Types in Salangs

Causes of deterioration	**Category**
Horizontal movement or displacements of girders including bridge vibration due to normal transportation and bearing pad damage.	Imperfect design or construction
Erosion of riverbed, exposure bridge foundation, debris flow, sediment, and wing wall damages.	Scour
Broken precast slab elements, the vibration of slabs due to excessive vehicle loads, and shortening services life of the bridge.	Overloading
Damage to guardrails, sidewalks, accidents of vehicles with bridges.	Collision
Drainage blocking, Damage of expansion joints, guardrail, sidewalk, approach slab, including sediments cleaning and existing debris in abutments, etc.	Lack of regular inspection and maintenance

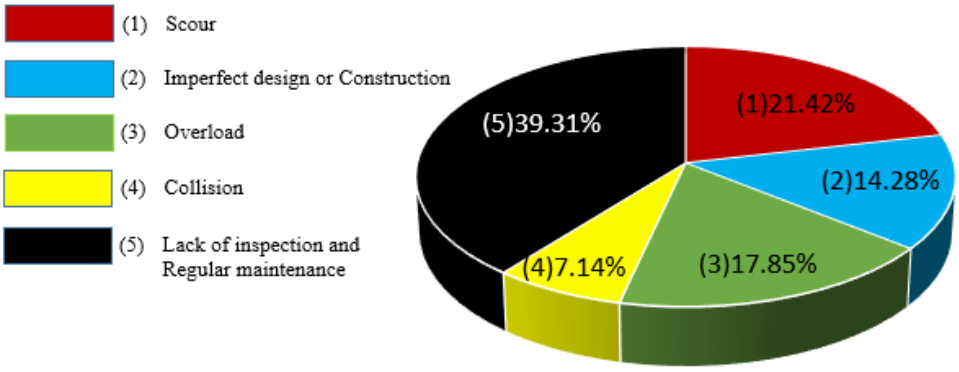


Fig. 4. Distribution of causes of the 29 existing bridges deterioration observed in the entire north and south Salangs

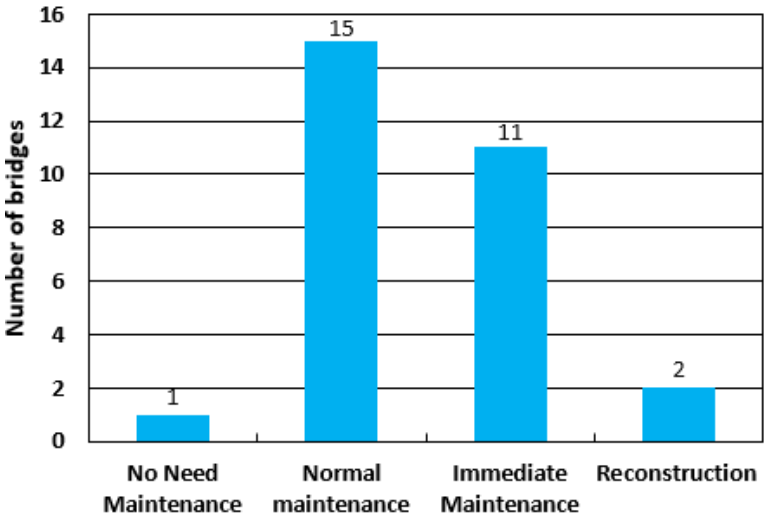


Fig. 5. Shows the bridges conditions and types of maintenance required based on existing deficiencies and risk of bridges failure

5. Causes of Bridges Deterioration in Salangs

Here, the causes of bridge deterioration were investigated numerically to identify the most frequent type that happens on the Salangs highway. Although, this highway has the most crucial role in the connectivity of the northern and central regions of the country, as already explained in detail in section 3 of the paper. It still experienced the worst challenge against transportation from the infrastructure point of view, and need for deep investigation to cope with this tough challenge. Thus, initially, the degradation reasons of the bridges were categorized in Table 3 to simply know the more effective factors that make the bridges' deterioration and functionality obsolete, also it is important to describe the factors that contribute to bridges' deterioration numerically for better understanding.

The outcome obtained from the quantitative investigation shows, that degradation occurs due to the following reasons: 21.42% scour, 14.28% imperfect design or construction error, 17.85% overloaded, 7.14% collision, and 39.31 lack of maintenance as shown in Figure 4. The other factors such: as wind, earthquake, fire …etc, either don’t have a significant influence or may have a slight impact which can be ignored. Indeed, Figure 4 provides a comprehensive and complete description of the causes of bridge deterioration.

Additionally, this research shows that all bridges require urgent maintenance, rehabilitation, or new construction except one of them as seen in Figure 5. This figure demonstrates the current structural condition for appropriate maintenance. It is easily understood from the figure that bridge infrastructure not only doesn’t function well for services but also may lead to collapse in the future. That is to say, the outcome achieved from this study indicates both the causes of bridge deterioration and structural condition

aspects, for better planning and effective maintenance as shown in Figure 4 and Figure 5 respectively.

6. Results and Discussions

A quantitative and qualitative investigation was conducted for each single bridge in the entire Salangs to evaluate the causes of deterioration, current situation, and functionality of the structure elements. Firstly, the bridge elements were inspected, and their deficiencies, type of damage, and condition including reasons for deterioration have been focused to depict completely the whole existing situation for appropriate repair, maintenance, and management.

The present study shows, that many factors cause the deterioration and failure of bridge infrastructure explained briefly in section 2 of this paper. Among the mentioned factors, some of them influence the bridge deterioration significantly in Salangs and need to be addressed properly. Table 2 provides a comprehensive and complete description of the bridge degradation root. According to the type of deterioration in Table 2, all bridges were specifically classified into five categories based on their defects and then set in Table 3. This helps us to decide and make more real planning for better maintenance and provide information regarding the root of bridge degradation. More precisely, the investigation outcome demonstrates that deterioration causes consist of imperfect design or poor quality construction, scour, overloading, collisions, and lack of sufficient inspection and maintenance as indicated in Table 3.

Figure 4 shows, the percentage of deterioration reasons obtained due to quantitative studies, and here will be discussed. Scour made 21.42 % of bridge degradation due to erosion and riverbed demolition around the pier foundation of bridges through water flowing in salangs. In addition, the water flow alignment and pattern have been changed as a result of sediments away from the pier foundation and the water flow tends to run from one side near to pier foundation, whereas the other side of the river is dried. It is required to protect the foundation by repairing and regularly cleaning the riverbed from debris, as well as extra sediments and this problem can be solved easily.

Regarding imperfect design or construction error, many technical problems were observed and made up almost 14.28 % of bridge deficiencies. The girder of some bridges has been displaced laterally due to moving heavy vehicles as shown in Figures 3B and 3C as examples. This is because the bridges were located in a sharp horizontal curve and caused displacement in one direction due to crossing vehicles. Here, the study proposes a specific solution to prevent girder movement which is a contributing factor to bridge deterioration and can result in collapses as well. To restrain the girder laterally it is better to build shear keys between girders, the shear keys support the girder from each side and provide resistance against the girders' movements. In Salangs, most bridges may be due to imperfect design or poor quality in construction don’t have both shear keys and sufficient diaphragms to make girders as single elements. Furthermore, other deficiencies are found on the bearing pad. Hence, It is proposed to replace the bearing pads that need to be used new that have sufficient resistance.

Overload has caused 17.85 % of the deterioration of bridges in salangs. Some elements of precast slabs have been broken and even become separated from each other. The

field observation indicates huge rutting on the bridge surface and even made the road-wearing layer to be in worse condition. The bridge inventory needs to control the transportation when passing on the highway. In the country, some regulations control overloaded, thus, the rule needs to be employed. Additionally, 7.14 % of deterioration is owing to collision, particularly the guardrails are destroyed as a result of accidents, and even in some cases many people lose their lives. Regarding collisions, it is proposed a signboard should be erected to show the speed of drivers, at present there is no signboard, road marking, or signal system to instruct transportation and speed control.

As indicated in Figure 4, almost 39.31 % of bridge deterioration is a result of inadequate inspection and maintenance. Field inspection demonstrated that most of the deficiencies occurred owing to insufficient maintenance and slowly it resulted in a big challenge for the bridge structure. Thus, it is needed to be carried out regular maintenance and management of bridges to keep them safe. Many, deficiencies like: cleaning and repairing expansion joints, bridge guardrail, giving protection coating for girder, cleaning abutment from debris, keeping open the drainage, cleaning the sediments from the riverbed, protecting of foundation from erosion, and repairing bridge surface, etc., including replacement of broken precast slabs are directly depended to regular inspection and maintenance. In general, it said that the main reasons for the deterioration in salangs are graded from insufficient maintenance (39.31 %), scour (21.42 %), overloaded (17.85 %), imperfect design or construction (14.28 %), and collision (7.14 %). This investigation shows that lack of maintenance is the major cause of collision is the minor cause of bridge degradation and the others are situated between these two factors.

Additionally, this study explores a significant classification of bridge conditions for appropriate or sophisticated maintenance and repairs. Here, the bridges are divided into four types: bridges with no need for maintenance, bridges with normal maintenance, bridges with immediate maintenance, and bridges that require total construction as shown in Figure 5. The study discovers that only one bridge which is recently constructed is safe and has no need for maintenance. Almost 15 need normal maintenance: normal maintenance means that the bridges require only cleaning the debris, repairing expansion joints, protecting the coating of the girder, etc. The normal maintenance indicates that the bridge structure is healthy and safe. Furthermore, immediate maintenance points out those bridges which partially or completely some structural members have been devastated and cannot function well causing a significant deterioration of the bridge, even in some bridges may result in collapses. As indicated in the figure, almost 11 bridges occur in this category. These bridges should be given priority for maintenance and management. It is mentionable, that because of economic restraint, it would be better to prioritize the bridges for maintenance and management. Finally, two bridges need construction due to the total deterioration of their slab and piers.

Hence, this study provided a complete depiction of the defects and condition of bridges in the south and north Salangs. As the Salangs highway is a tremendously important part of road infrastructure and connects the northern region of Afghanistan with the center of the country and the bridge infrastructure plays a key role in connectivity, it is

necessary to conduct regular inspection and monitoring for appropriate maintenance and management.

7. Conclusions

Bridges are the largest, most expensive, and most complex structures, which make them crucial and valuable transportation assets for modern infrastructure. Recently, most bridges are deteriorated and some of them are at risk of failure in Salngs. Mainly, deterioration and failure of bridges occur due to natural factors like flood, scour, wind, landslide, earthquake, etc, and human factors such as improper design, overload, lack of maintenance, collision, etc. The investigation indicates that most of the deterioration in Salnsgs is due to Scour, overload, lack of regular maintenance, collision, and imperfect design or construction error, these deteriorations include the superstructure and substructure of bridges. The investigation outcome demonstrated that a significant degradation of bridges has occurred in Salangs, more precisely can be summarized as; owing to insufficient maintenance (39.31 %), scour (21.42 %), overloaded (17.85 %), imperfect design or construction (14.28 %), and collision (7.14 %). The results indicated the major cause of deterioration is due to lack of proper and regular maintenance which is 39.31 % and the minor cause of bridge degradation is because of collision which made 7.14 %.

Additionally, the study revealed that a total of 29 bridges need either normal maintenance, immediate maintenance, or new construction except one of them which has been built recently. Of 29 existing bridges 11 number of them have severe conditions and are at risk of failure which should be cope with immediately otherwise may result not only in economics but also in the loss of human life. Thus, it is essential to develop an effective maintenance plan based on the information acquired from this paper to avoid bridge degradation and collapse.

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