Economic efficiency of road surface construction using the cold technology of recycling the asphalt-concrete in Iraq and Russian Federation

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Abstract. This article illustrates the state of roads in the Republic of Iraq and studies the possibility of using the cold regeneration technology of asphalt concrete as the base of the pavement. Moreover, it shows the economic efficiency of using the technology of cold regeneration of asphalt concrete in the asphalt plants and the roads, including crushing of granulate, cement and an aqueous solution of an emulsifier. As compared with the traditional methods of hot asphalt paving, the use of cold technology of recycling the asphalt concrete in (Iraq and the Russian Federation), shows remarkable advantages in both economic and environmental effects.

1. Introduction
For the last three decades, Iraq’s transport infrastructure has suffered from low funding. An extended period of economic sanctions and the lack of repair work contributed to the annual accumulation of wear on coatings and an overall decrease in the quality of transport services [1]. Highways provide 80% of all traffic in Iraq. The total length of the country’s road network is over 60 thousand km. 80% of roads have a non-rigid surface, 10% - Rigid pavement, 10% without hard surface [2,3]. Over 80% of the length of the road network in Iraq does not meet regulatory requirements because of untimely repairs [4,5].

Currently, the state of Iraq is going through an economic crisis and is unable to allocate a large number of funds for the construction and reconstruction of highways. It is assumed that the use of cold reclaim technology (CR) improves the properties of old asphalt concrete and reduce the cost of repairing road surfaces.

The cost of the road surfaces maintenance is determined from the cost of materials, energy resources, equipment repair costs, etcetera. In the past three years, the cost of materials Iraq has been increasing and fluctuates noticeably during the construction season (Fig. 1) [6,7,8].
Figure 1 above shows the costs increase in the materials for the previous two years due to the increases demand and decreases in their production.

The main costs for the production of mixtures include costs of raw materials and materials consumed in the production process; fuel and energy costs spent on technological purposes; the cost of purchased products and semi-finished products that undergo further additional processing and the cost of spare parts for repairs and specialised equipment.

The energy savings in road rebuilding depends on:

- The amount of additional new material and the distance of its transportation;
- The method of removing the old coating and the distance of its transportation;
- The method of crushing the asphalt concrete pavement and the distance of its transportation;
- Type of regeneration technology and location from the project;
- Amounts of moisture content of asphalt concrete and stone materials.

According to UNESCO data for 2018, the level of environmental pollution in the republic continues to grow (Fig. 2). That is primarily due to military events and the growth of road transport, especially in Baghdad and the surrounding area.

Figure 2. The level of environmental pollution according to UNESCO data.

Over six million vehicles are in Iraq, 33% of the vehicles are in Baghdad. The daily fuel consumption is 7 million litres. Environmental pollution by lead oxides exceeds the permissible level by six times, and the carbon dioxide (CO2) exceeds the permissible level by 70% [2]. The second factor of pollution is industrial waste and emissions, including emissions released during the production of asphalt concrete in the asphalt plants manufactures.

Pollution arising during the asphalt plants operations of Hot mixture affect the quality of atmospheric air, soil, groundwater. The production activity of factories leads to the various releasing pollutants into the environment, such as carbon and nitrogen oxides, hydrocarbons, soot, sulfur oxides, resinous substances, benzopyrene, vanadium oxide, phenol, formaldehyde. Therefore inorganic dust is the most dangerous (Fig. 3) [10,11].
To reduce the level of environmental pollution, the cost and timing of road repair work, it seems advisable to restore worn-out road surfaces in Iraq using the (CR) method. Cold mixes are prepared on the road (cast in place) or in the factory.

2. Results and Discussion

About 70% of the costs of maintenance pavements are the costs of producing asphalt concrete mixtures. Table 1 below shows the composition of the costs of the mixtures for the conditions in Iraq.

| Cost of materials | Energy costs | Labour and equipment repair | Profit | Total |
|-------------------|--------------|------------------------------|--------|-------|
| 21                | 3            | 4,2                          | 1,8    | 30    |

The analysis of the technological process of production and paving of asphalt concrete mixtures shows that the base energy consumption spent on the preparation of mixtures. In this case, more than 80% of energy resources (electricity, gas or diesel fuel) in the process of preparing mixtures are for the drying and heating materials in the drying drum of an asphalt mixing plant [9].

One of the main ways to reduce costs when introducing (CR) technology in the Republic of Iraq is the optimal selection of used road building materials with a preliminary study of their properties.

Table 2 shows the materials costs in Russia (Moscow/Rubles) and Iraq (Baghdad/USDollar). The mixture obtained as a result of cold reclamation is called asphalt granule concrete (AGC).

| Materials                        | Unit | Cost in RUB excluding VAT | Cost in USD excluding VAT |
|----------------------------------|------|---------------------------|---------------------------|
| Cement m500                      | T.   | 3700                      | 100                       |
| Water                            | T.   | 100                       | 8                         |
| Plasticiser                      | T.   | 12700                     | 240                       |
| Uncrushed old asphalt concrete granulate | T.   | 670                       | 6,5                       |
| crushed granulate of old asphalt concrete | T.   | 750                       | 8                         |

Table 3 shows The cost of the main types of work on the construction of asphalt granules concrete (AGC) coatings for the conditions of Russia (Moscow) in rubles and Iraq (Baghdad) in dollar terms.
Table 3. The cost of work on the construction of an asphalt-granular concrete pavement.

| Name of works | Unit | Cost in RUB. | Cost in USD. |
|---------------|------|--------------|--------------|
| Milling old asphalt concrete | T. | 520 | 4 |
| Transportation of granules to the plant at a distance of up to 10 km | T. | 150 | 2.5 |
| Crushing granules at the plant in a crusher | T. | 80 | 1.5 |
| Cold mix preparation | T. | 165 | 2 |
| Transportation of AGC mixture from the plant by dump truck up to 10 km | T. | 150 | 2.5 |
| Paving of AGC mixtures with compaction with rollers. | m² | 120 | 1.75 |

Cold regeneration technology can significantly reduce the cost of mixtures, as well as reduce harmful emissions and reduce energy costs.

The calculations for four variants mixtures of (AGC) for the conditions of the Russian Federation in rubles, and the Republic of Iraq in dollars have been done, see (Table 4).

Table 4. Compositions of AGC mixtures with granulate 0-40 mm and granulate 0-20 mm.

| Materials | Before crushing | After crushing |
|-----------|-----------------|----------------|
|           | Comp.№ 1 | Comp.№ 3 | Comp.№ 1 | Comp.№ 6 |
| A) Granulate of old asphalt concrete (100% fraction 0-40 mm) | 100% | 95.5% | 100% | 97.73% |
| B) Granulate of old asphalt concrete (60% fraction 5-20 mm and 40% fraction 0-5 mm) | - | 3% | - | 1.5% |
| Cement m₅00 | - | 1.5% | - | 0.75% |
| Water | - | - | - | 0.018% |
| Plasticizer | - | - | - | 0.018% |
| Total: | 100% | 100% | 100% | 100% |

As a result, the average cost of 1 ton of hot fine-grained dense asphalt concrete mixture (type B) is 2500 rubles for Moscow, Excluding VAT, however, for Baghdad, the cost of a similar mixture is 30.00 USD.

For the comparison of the cost of materials by options in the factory, see Figure 4.

Figure 4. Comparison of the cost of coverage by options in the asphalt plant:

a-Russia (Moscow); b-Iraq (Baghdad).

- granules (0-40mm) without cement;
- granules (0-40mm), 3% cement;
- hot coarse-grain mixture (type B);
- fractionated granules (0-20mm);
- fractionated granules (0-20mm) with cement;
From the data obtained, it follows that the cost of (AGC) mixtures with crushed granules, plasticiser and cement (1.5%) obtained in the asphalt plant does not significantly differ from the cost of a similar mixture without crushing with cement (3%) used for cold regeneration on-site, while the cost AGC is 2.5 times less than the cost of hot asphalt concrete mix (type B).

For Moscow, the cost of 1m$^2$ of a hot coarse-grained dense asphalt-concrete mixture is 660.24 rubles. Excluding VAT, for Baghdad, the cost of coverage from a similar mixture is 11.51 USD.

Figure 5 shows a comparison of the cost of asphalt concrete pavement (1m$^2$) with a thickness of 10 cm in the Asphalt plant between both countries.

Cold regeneration technology in the road is not used yet in Iraq. Therefore the calculations are performed for the conditions of the Russian Federation.

For our calculation, we selected the most commonly used technology using a recycler (WR 2500).

The milling asphalt width is 2 m, but in some specific cases, the milling width can increase to 2.5 m. and the milling depth reaches to 30 cm.

The speed of the machine significantly depends on the milling depth and averages 5 - 7 m / min.

Average working productivity per shift is 1.5 km/day depending on the depth and the width of the milling and the current situation on the site.

The proposed width of the milling is 2.5 m, and the length of the section is 1500 m with a thickness of 0.1 m. The productivity per shift is 3750 m$^2$ or 937.5 T / shift.

The duration of the shift is 8 hours, which means 117 T / hour. and as a result, the cost of a water tanker is 12.8 rubles / T.

Figure 6, summarizes the comparison of the cost of AGC pavement (1m$^2$) 10 cm thick in the asphalt plant and the site.
Figure 6. Comparison of the cost of coverage in the asphalt plant manufacture and on the site by options (Comp.№ 1, Comp.№ 3 and Comp.№ 6) respectively:

In the asphalt plant; in site.

3. Conclusion

- The use of cold regeneration technology has a significant economic effect in comparison with the traditional hot mixture technologies.
- The performed calculations for comparative variants of mixtures and coatings for the conditions of Moscow and the requirements of the state of Iraq showed that the use of old asphalt concrete granulate could significantly reduce the cost of AGC mixture.
- The calculations showed that the most economical technology for improving the physical and mechanical characteristics of the mixture is the technology that provides for the device of a coating or base from crushed fractionated granulate of fractions 0-20 mm with the addition of cement and a plasticiser. For 1 m² of coating 10 cm thick, saving according to the selected option No. 6, in comparison with the hot coarse-grained mixture (type B), is 284.08 rubles for Moscow and USD 6.45 for Baghdad.
- The cost of regeneration in the plant is slightly higher if compared to CR in the road site due to transportation costs and additional crushing and sieving operations. At the same time, the characteristics of the AGC mixture prepared in the asphalt plant are higher, also higher than the calculated features of the AGC. That makes it possible to obtain additional economic efficiency by reducing the thickness of the coating layer.

4. References

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